WATER RESOURCES WHITE PAPER

Prepared for consideration by the Delta Stewardship Council

December 8, 2010

Not reviewed by or approved by the Delta Stewardship Council

Send comments to deltaplancomment@deltacouncil.ca.gov.

All comments received are posted to the Delta Stewardship Council web site: http://www.deltacouncil.ca.gov/

Executive Summary

Water supply in California is dependent upon geography, climate, upstream patterns of use and return flows, and facilities to store and convey water resources. Total precipitation in California results in water flows that can range from less than 150,000,000 to more than 350,000,000 acre-feet per year (Department of Water Resources [DWR], 2009). Most of the precipitation occurs between November and April, with 50 to 60 percent of the precipitation occurring in the northern and Central Valley— the Delta watershed. In drier years as water demands increase, flows to the Delta decrease and demand for exports from the Delta increases.

Since the beginning of European settlement of California the late 1700s, communities and agricultural areas constructed dams and canals to convey water from major rivers to the new communities, farms, and ranches. In the early and mid-1800s, local irrigation projects were constructed to support these beneficial uses. In the late 1800s, two innovations led to the expansion of irrigated agricultural acreage. First, the new transcontinental railroads supported expanding markets for California crops and easier migration. Second, gasoline engines were adapted to drive pumps, allowing deep groundwater wells. As the demand for irrigated agriculture grew, large diversions and conveyances were constructed. Some of the earliest diversions occurred in the Tulare Lake Region on the Kaweah, Kern, Kings, and Tule rivers. Several events further drove water supply development: numerous droughts in the late 1880s, continued expansion of agricultural markets that led to major groundwater overdraft in portions of the Central Valley and unreliable water supplies, and projections for continued growth in the San Francisco Bay Area and Southern California. In response, eight major water facilities were constructed in California: San Francisco Public Utilities Commission's Hetch Hetchy Project, Los Angeles' Owens Aqueduct, Imperial Irrigation District's All American Canal, East Bay Municipal Utility District's Mokelumne Aqueduct, Los Angeles' Mono Lake Aqueduct, Metropolitan Water District of Southern California's Colorado River Aqueduct, the Bureau of Reclamation's Central Valley Project (CVP), and the State Water Project (SWP). In 2005, these major water projects provided water throughout most of the state, serving more than 34 million people and over 4 million irrigated acres (3 million acres by CVP, 600,000 acres by SWP, and 500,000 acres by Imperial Irrigation District).

As these and other smaller water resources projects became fully operational, plans continued to be developed for additional expansion of projects to further reduce groundwater overdrafts. These projects, such as Mid-Valley Canal, were not completed because reliable water supplies were lacking.

Numerous litigations and regulations have changed water facilities operations to protect all watershed beneficial uses, including use of diverted water within the watershed and within the export service area by municipal, industrial, agricultural, and tribal users; aquatic and terrestrial habitats; recreation; and navigation. All of these beneficial uses require the availability of reliable water supplies with appropriate water quality. Continued water diversion in historical patterns and periodic droughts will not allow for balanced and reliable water supplies with appropriate water quality for all beneficial uses.

Since the historic drought of 1976 and 1977, many municipalities and agricultural areas have implemented major water use efficiency measures to allow continued growth without additional water supplies. However, continued occurrence of droughts and restrictions on diversions of water to protect aquatic habitat and other water users (in the Delta, Owens Lake, Mono Lake, Pardee and Camanche reservoirs into the Mokelumne Aqueduct, and Colorado River) have reduced water availability to major municipal and agricultural areas of California. Some areas that are reliant upon imported CVP and SWP water supplies and precipitation in surrounding mountains have found it difficult to slow or reverse the continuing groundwater overdraft. For example, the Tulare Lake Region has experienced groundwater overdraft since the 1880s. During wet years, local runoff and primary use of imported CVP and SWP water allows groundwater elevations to rise. However, this groundwater replenishment cannot keep pace with normal and dry year use, so groundwater elevations continue to decline. In the past 20 years as the CVP and SWP systems were fully constructed and Delta exports were reduced to protect aquatic and terrestrial habitat, CVP and SWP exports to the Tulare Lake Region have declined from their levels in the 1960s through 1980s, resulting in greater reliance on local supplies. The combination of these conditions has further exacerbated groundwater overdraft. A water emergency has been issued for the Central Coast basin in Southern California due to declining water levels that are near historic lows in some areas.

During the past few years, all regions of the Central Valley and areas of California that use water exported from the Delta watershed have developed programs to reduce the consumptive use of water, reduce overall water diversions, and improve water quality and aquatic and terrestrial conditions in the Delta watershed. However, the available water supply and water quality is not sufficient for all the beneficial uses. The availability of water supply could be further reduced as sea level rise extends the reach of salt water further into the Delta and reduces the availability of water supplies with appropriate water quality for municipal and agricultural users. Climate change could reduce snowpack in the mountains, which would change the availability and management of water supplies in complex ways. Air temperature could also be affected by climate change, potentially leading to increased consumptive use by riparian and wetland vegetation as well as water demand for agricultural crops throughout the Central Valley. All of these future scenarios would further reduce the availability of reliable water supplies for all beneficial uses.

This white paper is intended to describe the development of facilities and jurisdictional requirements over the past 150 years that have addressed beneficial uses, potential and real conflicts between those uses, and future risks. This white paper provides a summary of historical and existing conditions, but does not provide specific details such as operational criteria for water systems that divert water from the Delta watersheds. This white paper does not address methods to reduce the risks or reduce existing or potential adverse conditions in the Delta. Additional information will be provided in the Existing Conditions and Affected Environment sections of the EIR, including:

- Surface water flows and water quality characteristics
- Groundwater use and quality
- Facilities used by the SWP, CVP, and other major water systems
- Historical and existing water use, and a comparison of water use and water supplies

The draft water resources section of Existing Conditions will be presented to the Council in February 2011.

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Section 1 Introduction

In November 2009, the California Legislature enacted SBX7 1 (Act), one of several bills passed at this time related to water supply reliability, ecosystem health, and the Delta. The Act became effective on February 3, 2010.

In the Act, the Legislature declared that the Delta (which the Act specifies to include the Sacramento–San Joaquin Delta and Suisun Marsh) is a critically important natural resource for California and the nation. It serves Californians concurrently as the hub of the California water system and as the most valuable estuary and wetland ecosystem on the west coasts of North America and South America. The Legislature also declared that the Delta watershed and California's water infrastructure are in crisis, that existing Delta policies are not sustainable, and that resolution of the crisis requires fundamental reorganization of the State's management of Delta watershed resources.

The Legislature required development of the Delta Plan to meet the coequal goals and all of the inherent subgoals defined by statute. The plan must define an integrated and legally enforceable set of policies, strategies, and actions that will serve as a basis for future findings of consistency by state and local agencies with regard to their Delta-related projects, and for subsequent evaluation of those findings by the Council on appeal, as provided in statute and Council regulation. The coequal goals are defined by Water Code (Wat. Code) section 85054:

> *'Coequal goals' means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.*

Formed by the confluence of the state's two longest rivers—the Sacramento and the San Joaquin—the Delta is one of the most valuable and unique natural resources in the state and nation. Over the past 120 years, demands for water and land resources have become more competitive among ecosystem resources, agricultural users, municipal and industrial users, power generators, flood management operations in the watershed, and salmon fishing operations along the Pacific Coast. Despite the Delta's importance, the challenges of effectively addressing water resources, water quality, and other competing Delta beneficial uses have led to increased conflicts over time.

As an initial step in the development of the Delta Plan, white papers are being developed to summarize the following information:

- Historical activities that have contributed to existing conditions and current uses of Delta resources
- Jurisdictional responsibilities;
- Current conditions related to uses of Delta resources
- Future issues related to Delta resources

The white papers are not intended to describe the existing and projected conditions in detail. The more detailed discussions of existing and projected conditions will be presented in the Delta Plan Environmental Impact Report (EIR). Draft versions of the EIR chapters related to the existing and projected future conditions without implementation of the Act will be provided in early 2011 for review by the Delta Stewardship Council and the public.

Purpose and Use of this White Paper

This white paper is intended to describe the development of facilities and jurisdictional requirements over the past 150 years that have addressed beneficial uses, potential and real conflicts between those uses, and future risks. This white paper provides a summary of historical and existing conditions, but does not provide specific details such as operational criteria for water systems that divert water from the Delta watersheds. This white paper does not address methods to reduce the risks or reduce existing or potential adverse conditions in the Delta. Additional information will be provided in the Existing Conditions and Affected Environment sections of the EIR, including:

- Surface water flows and water quality characteristics
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The draft water resources section of Existing Conditions will be presented to the Council in early 2011.

Statutory Requirements

The Act (Wat. Code section 85020) stated that the policy of the State of California is to achieve the following objectives that the Legislature declares are inherent in the coequal goals for management of the Delta:

> (a) Manage the Delta's water and environmental resources and the water resources of the state over the long term.
>
> (b) Protect and enhance the unique cultural, recreational, and agricultural values of the California Delta as an evolving place.
>
> (c) Restore the Delta ecosystem, including its fisheries and wildlife, as the heart of a healthy estuary and wetland ecosystem.
>
> (d) Promote statewide water conservation, water use efficiency, and sustainable water use.
>
> (e) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.
>
> (f) Improve the water conveyance system and expand statewide water storage.

(g) Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses, and investments in flood protection.

(h) Establish a new governance structure with the authority, responsibility, accountability, scientific support, and adequate and secure funding to achieve these objectives.

For this effort, the Delta Plan will address areas that provide water to the Delta and areas that use water from the Delta, including the Delta watershed, because water management activities in these areas affect or could affect Delta water resources and water quality. The paper discusses natural sources of water, how water is used in the state, and the development of water supply by maximizing local supplies, developing interbasin transfers, implementing water conservation, and desalination of water. The paper also includes a discussion of how climate change will impact Delta water supplies.

Section 2
Water Use in California

This section of the white paper will explain how and where water is used in California. Water use in California is described using three categories;

(1) Water for urban (commercial, industrial, and residential) use

(2) Water for agricultural use

(3) Water used to sustain environmental needs (described in the California Water Plan as environmental use).

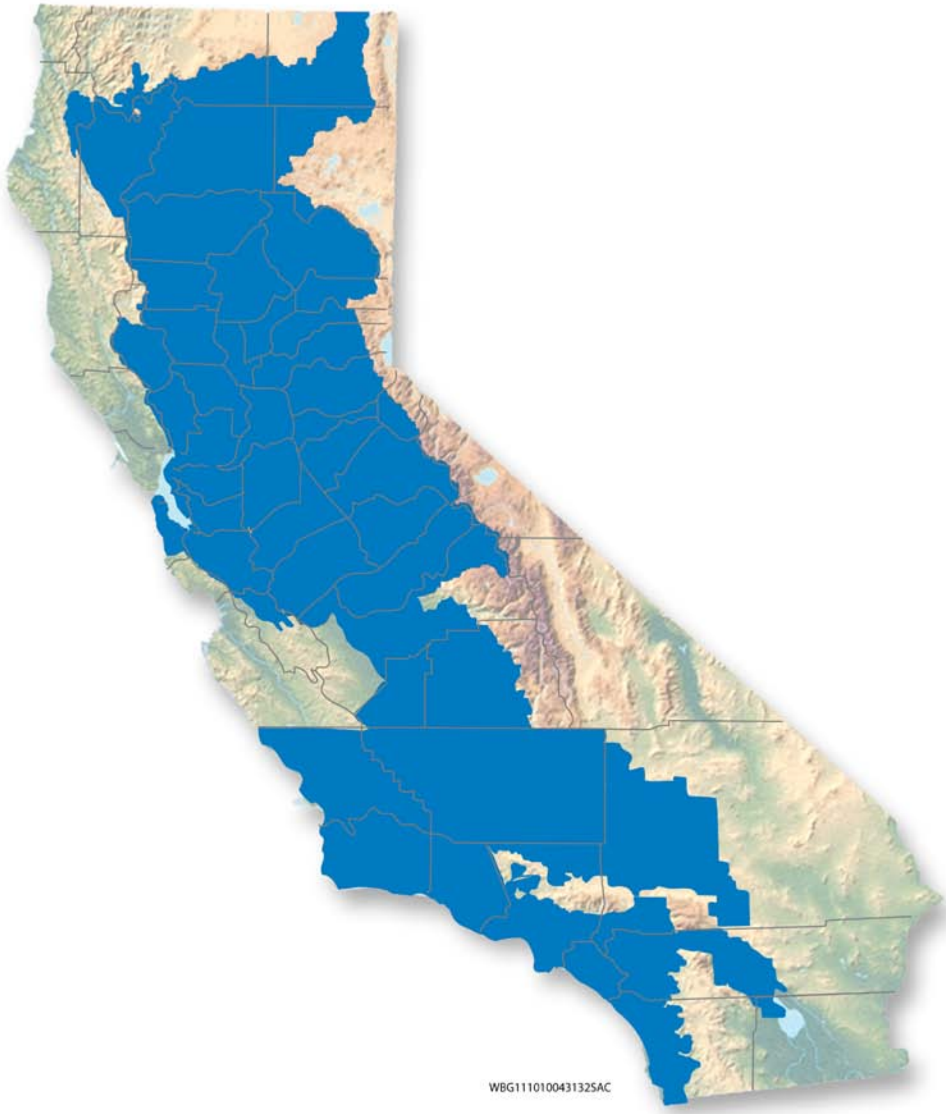
This white paper makes frequent use of statewide and regional water supply and use data published in the 2009 California Water Plan Update (DWR, 2009), which are based on water balances for the years 1998-2005. The data do not reflect impacts on water supply and water use that result from the 2007-2009 drought or recent court decisions and changes to biological opinions, which have reduced the amount of water available for export.

Background

Water use in California evolved with the development of water supplies throughout the state. The invention of the motorized pump led to intensive use of groundwater for irrigation in the early 1900s, driving the growth of agriculture in some areas of the Central Valley. As major water supply projects were developed to offset overuse of groundwater in some areas, additional water supplies became available for more water-scarce areas, matching growth in urban areas and moving water into other areas to support irrigation.

Because a large percentage of California’s water runoff naturally flows out through the Delta, the Delta watershed has played a significant role in the development of water supplies, and has also been significantly affected by that development. The Delta Plan will address areas that provide water to the Delta and areas that use water from the Delta, including the Delta watershed, as shown in Figure 2-1. Including areas of California reliant on Delta water in the Delta planning area is important because water management activities in these areas affect or could affect Delta water resources and water quality.

Figure 2-1
Areas that Provide Water to the Delta and Use Water from the Delta



Water use is impacted by water availability and varies based on precipitation, available runoff, and water demand. Wet years (i.e., higher rainfall) result in lower water demand while drier years (i.e., less rainfall than average) have a higher water demand. Demands are primarily driven by agricultural irrigation needs and urban demands, and recently more water is being allocated to support the environment.

Precipitation and Runoff

Precipitation is the primary source of water in California but varies seasonally, geographically, and annually. Precipitation produces water supplies ranging from less than 150 million to more than

350 million acre-feet per year (DWR, 2009). Precipitation in California occurs primarily between November and April, and most precipitation occurs in the mountains of eastern and northern California as seen in Figure 2-2. The variability of precipitation results in a mismatch between water availability and water needs.

Precipitation varies widely on an annual basis with cycles of higher than average and lower than average (droughts) rates as seen in Figure 2-2. This figure shows major droughts in the state including the droughts of 1912-13, 1918-20, 1923-24, 1929-34, 1947-50, 1959-61, 1976-77, 1987-92, and 2007-09 (DWR, 2010a) as well as the wetter than normal years. The unpredictability and variations in precipitation that occur in California make relying on precipitation as well as the resulting runoff for water supply impractical.

Figure 2-2
Average Annual Precipitation in California
Source: USGS, 2010

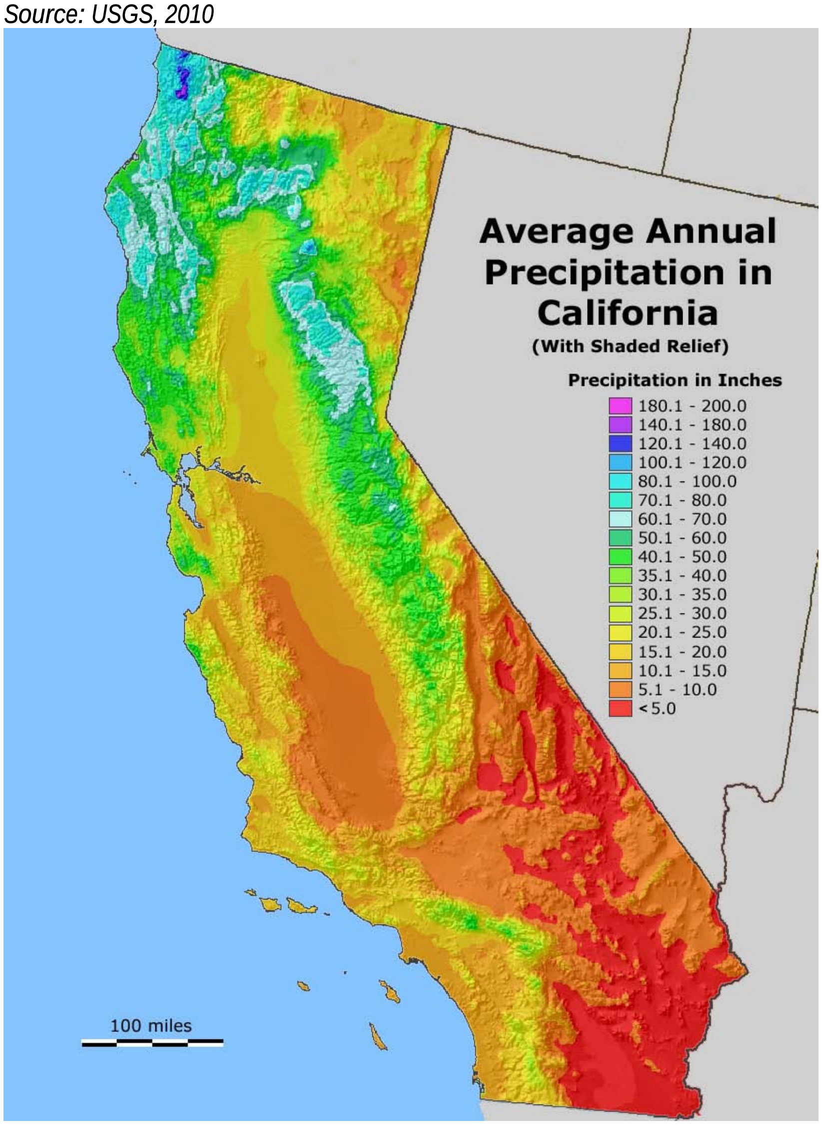
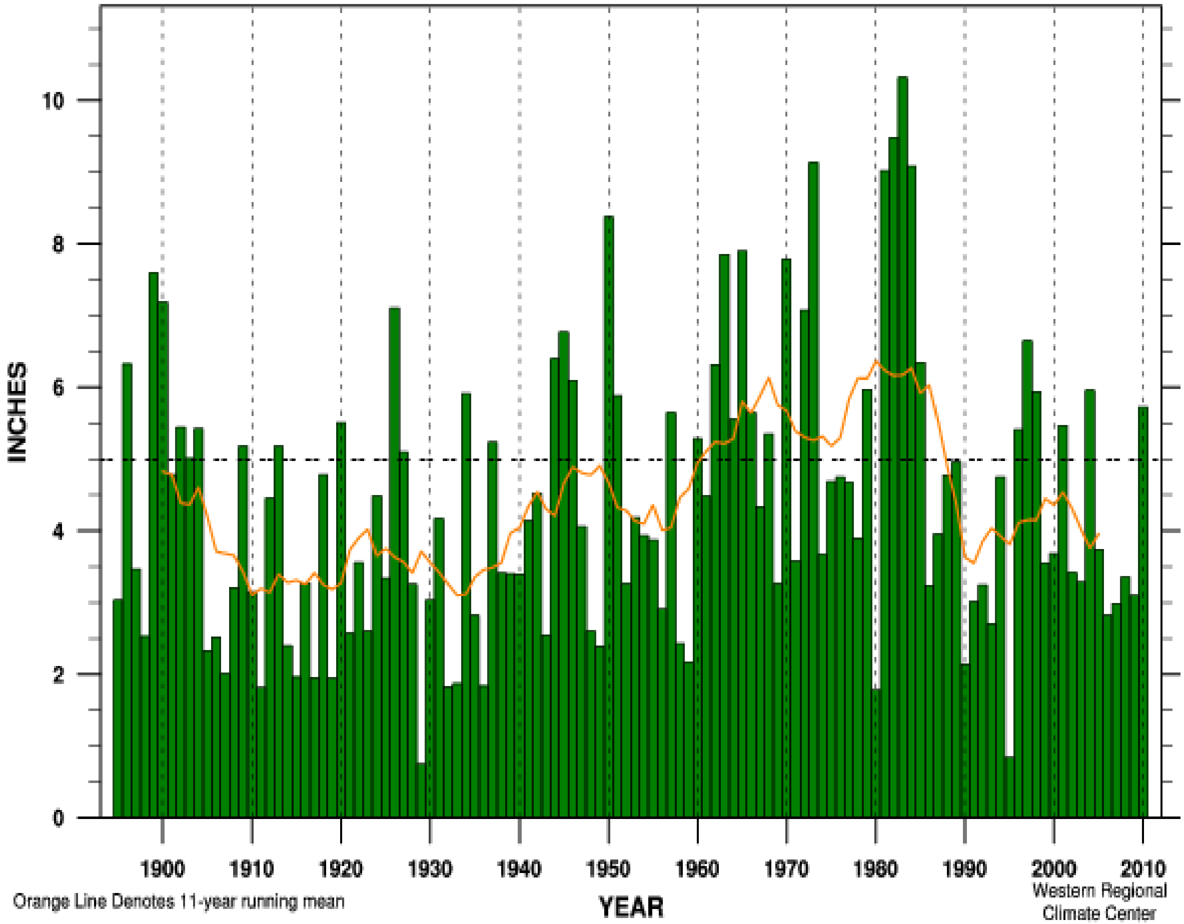


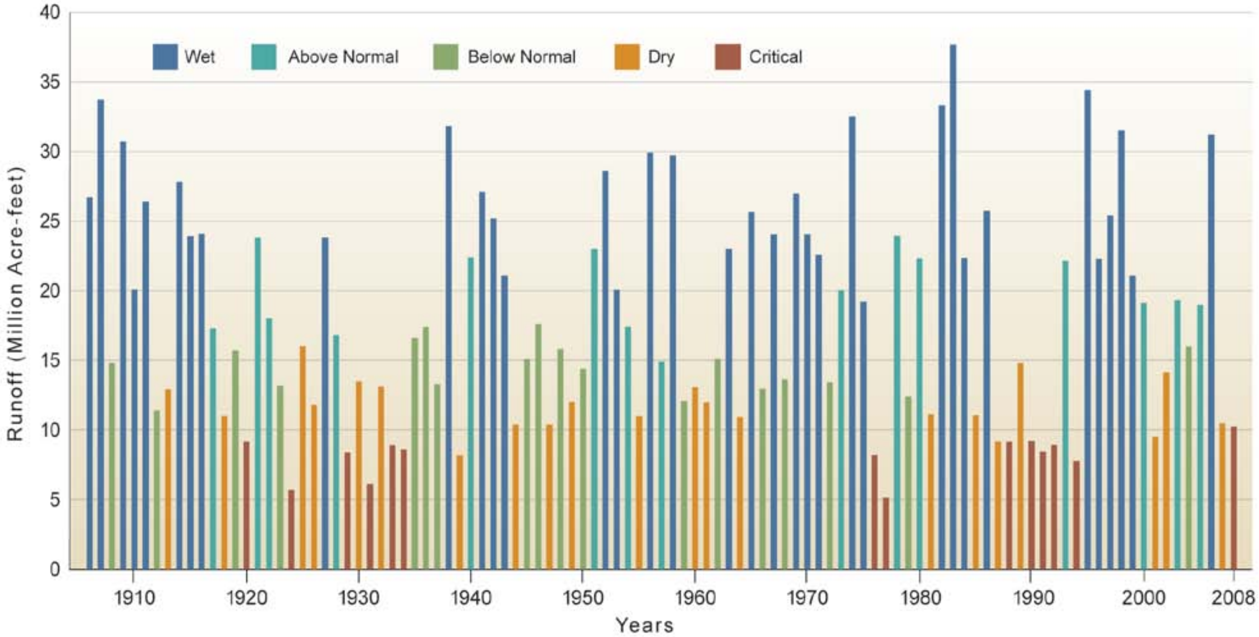
Figure 2-3
Variability in Annual Precipitation in California (Jul- Nov)
Source: Western Regional Climate Center, 2009



In the Delta watershed and use areas, the most significant source of water is runoff from the Sacramento and San Joaquin rivers and their tributaries. These rivers outflow to the Sacramento-San Joaquin Delta and Suisun Marsh (Delta), which form a natural floodplain that drains approximately 40 percent of the state (DWR, 2009). Precipitation and runoff in the Delta region are the primary sources for water in the state.

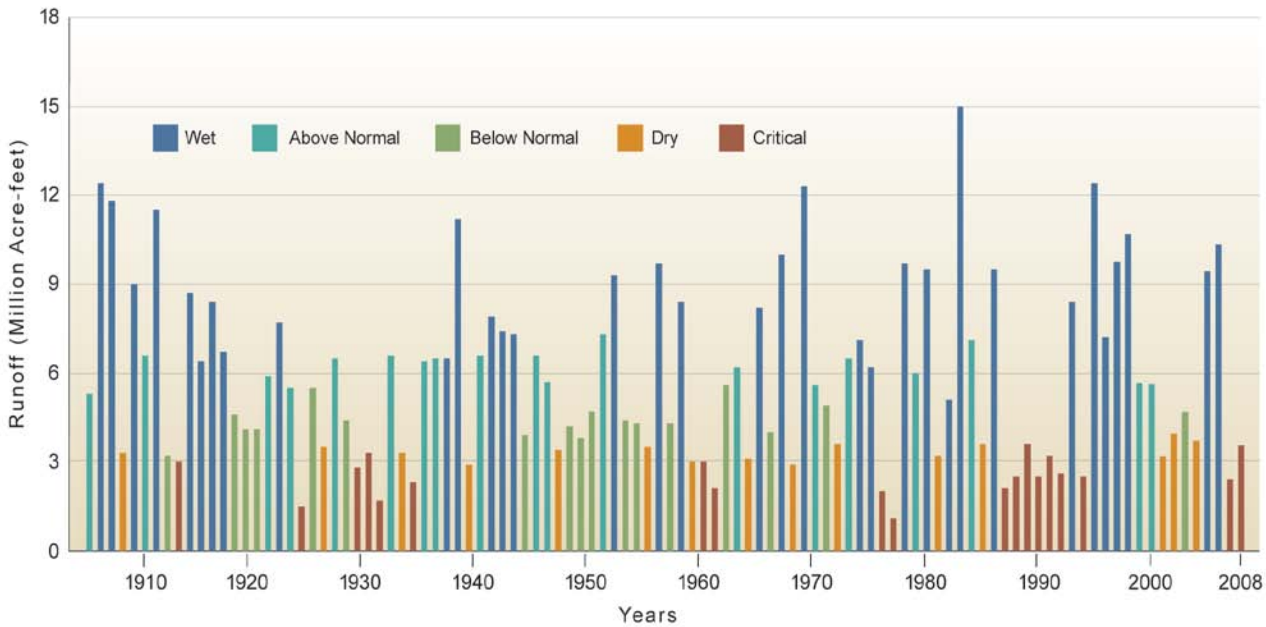
Precipitation in the coastal watersheds and in the lower elevations of the Delta watershed occurs primarily as rainfall or snow that melts quickly. Runoff from a rainfall event starts during the event and continues for several days following larger rainfall events. Snowmelt from the mountains in the higher elevations of the Delta watershed occurs in March through June in the northern portions of the Central Valley (i.e., Sacramento Rivers and its tributaries) and April through July in the central and southern portions of the Central Valley (i.e., San Joaquin River and tributaries). Runoff from the snowpack in the Delta watersheds could be 5 to 15 percent of the total runoff into the Delta. Figures 2-4 and 2-5 show the variability in annual runoff as well as highlight dry years on the Sacramento and San Joaquin Rivers and their major tributaries. The variability between high runoff years (e.g., over 35 million acre-feet on the Sacramento River) and dry years (e.g., approximately 5 million acre-feet per year on the Sacramento River) illustrates the problem of relying on unimpaired runoff for a consistent water supply. For this reason, major water supply projects have been developed in the state to capture, store, and convey water. These projects will be described in Section 3.

Figure 2-4
Sacramento Four Rivers Unimpaired Runoff, 1906-2008
Source: DWR, 2009



The Sacramento Four Rivers are: Sacramento River above Bend Bridge, near Red Bluff; Feather River inflow to Lake Oroville; Yuba River at Smartville; American River inflow to Folsom Lake

Figure 2-5
San Joaquin Four Rivers Unimpaired Runoff, 1906-2008
Source: DWR, 2009



The San Joaquin Four Rivers are: Stanislaus River inflow to New Melones Reservoir, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to New Exchequer Reservoir, San Joaquin River inflow to Millerton Reservoir.

Population

Water use is commonly discussed on a per capita basis; therefore, understanding the population distribution in the state is important. In 2009, California's population was estimated to be approximately 36.5 million as shown in Figure 2-6. The Department of Finance (DOF) estimates that population in California will continue to grow to approximately 60 million by 2050 (DWR, 2009). Population growth has slowed from a high of 2 percent between 2000 and 2001 to less than 1 percent between 2008 and 2009 (DOF, 2009).

Figure 2-7 shows the distribution of the state's population by county. Population in the state is highest in southern California as well as the San Francisco Bay and Sacramento areas. Los Angeles County has the largest population in the state. The state's nine largest counties are Los Angeles, San Diego, Orange, Riverside, San Bernardino, Santa Clara, Alameda, Sacramento, and Contra Costa. These counties compose over 70 percent of the population of California and all rely on Delta water for supply. Water from the Delta or its tributaries supplies all of the counties within the state that have populations in excess of 500,000. The population of these areas is also growing; between 2000 and 2009, the largest population gains in the state were in Los Angeles, San Diego, Orange, Riverside, and Santa Clara counties.

Figure 2-6
California Population
Source: DOF, 2009

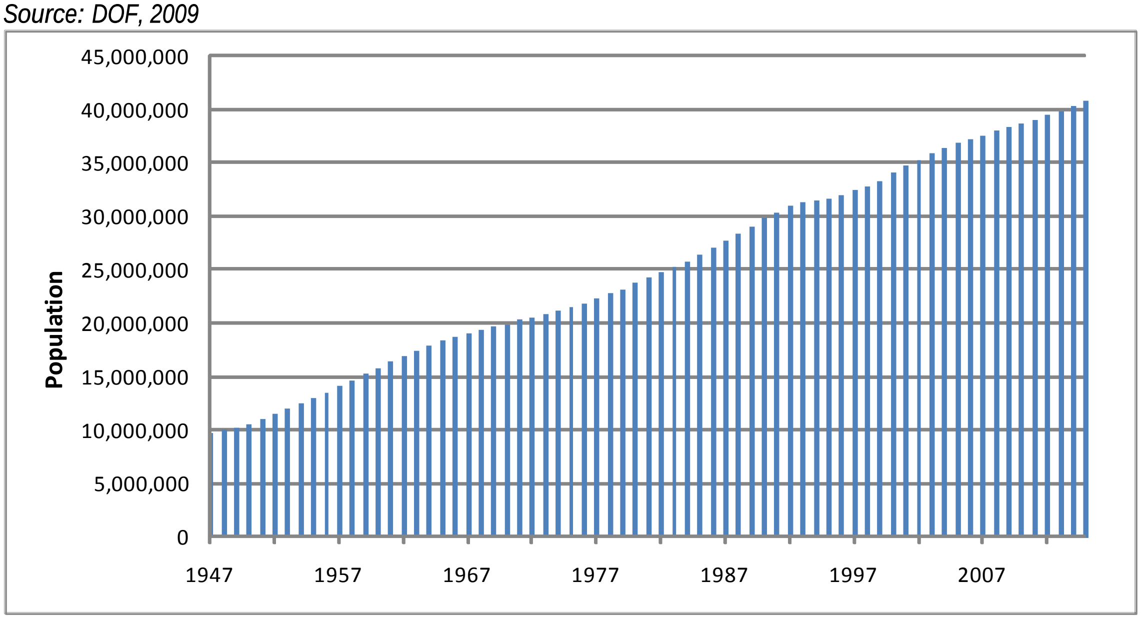
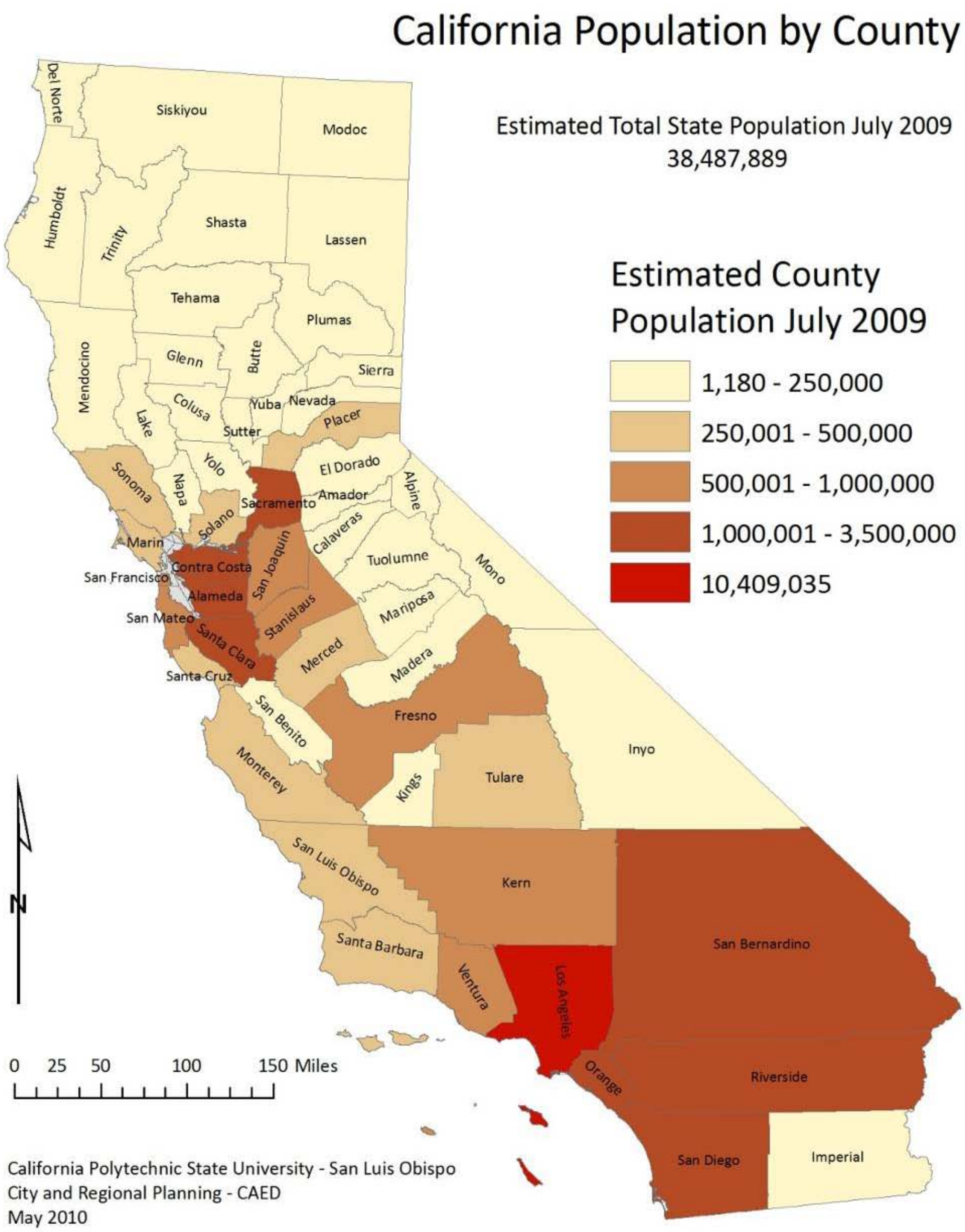


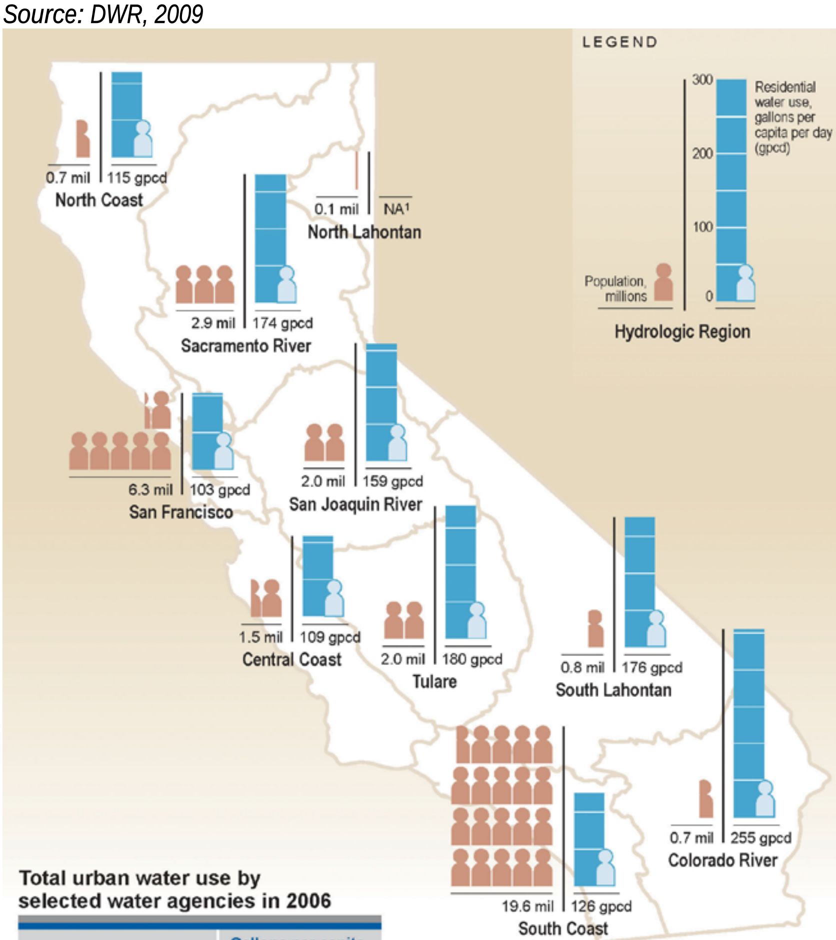
Figure 2-7
California Population by County
Source: CalEMA, 2010



Urban Water Use

Statewide, urban water use, per capita, averaged 192 gallons per capita day (gpcd) in 2005. The lowest per capita water usage in the state is in the Southern California and San Francisco Bay Areas, California's most populous regions, as shown in Figure 2-8. Per capita usage is lowest along the Pacific Coast and highest in the interior regions of the state, particularly the Tulare Lake, South Lahontan, and Colorado River regions, where low precipitation and higher temperatures increase the amount of water required to support irrigated landscaping.

Figure 2-8
Urban Water Use in California
Source: DWR, 2009



Total urban water use by selected water agencies in 2006

Water Agency	Gallons per capita per day
San Francisco	95
Santa Barbara	127
Marin (MWD)	136
Los Angeles (LADWP)	142
Contra Costa (CCWD)	157
San Diego	157
East Bay (EBMUD)	166
Victorville (VVCWD)	246
Bakersfield	279
Sacramento	279
San Bernardino	296
Fresno	354

Developed by DWR staff using PWSS date from 2006

1. *The North Lahontan Hydrologic Region does not have enough usable data in the Public Water Systems Survey (PWSS) database to compute for baseline values.*

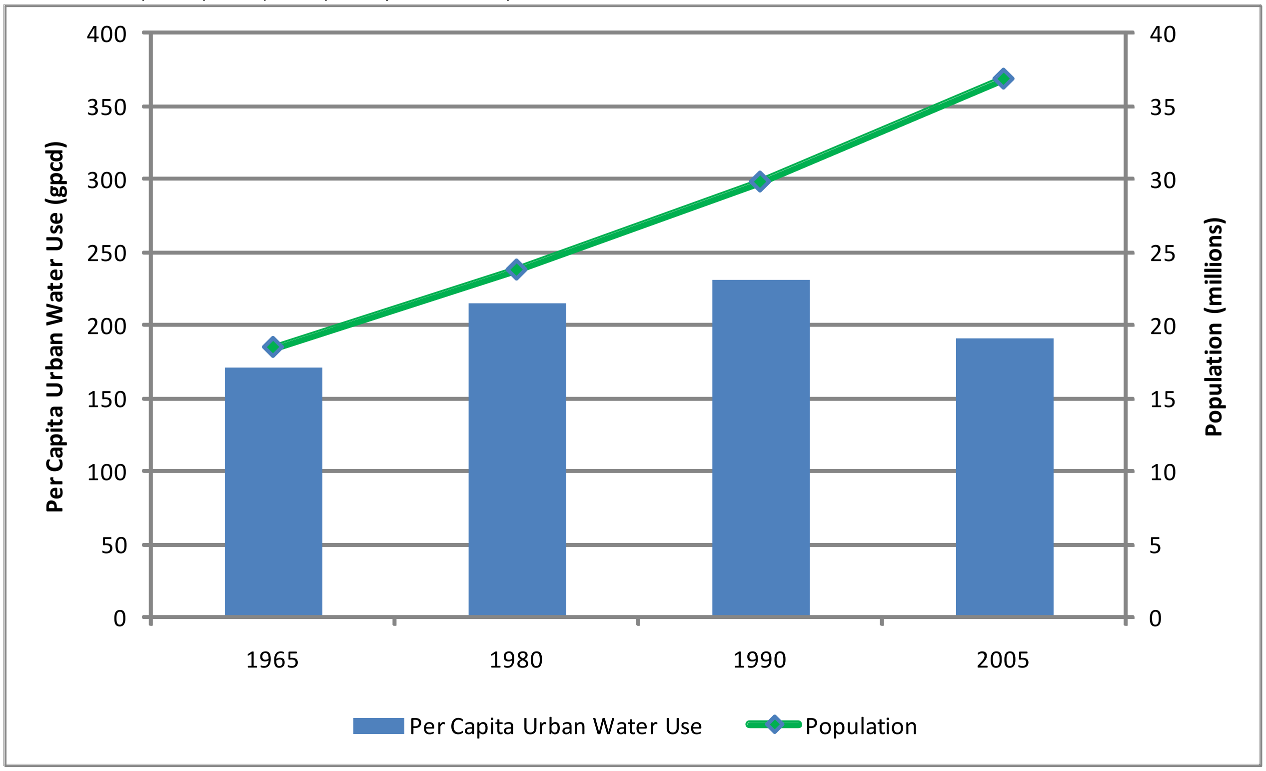
Population data source: CA Department of Finance. 2006. *Report E-4 Population Estimates for Cities, Counties and State, 2001-2006 with 2000 DRU Benchmark.*

Residential water use data source: 20x2020 Agency Team. *20x2020 Water Conservation Plan*. 2009.

The per capita residential water use numbers in this map were taken from the *20X2020 Water Conservation Plan*. Those numbers were developed using DWR's Public Water Systems Survey (PWSS) data, averaging available data from 1995 to 2005. The urban water use data in the portfolios in the Water Plan were developed using the PWSS data for specific years, not an average of years. Thus, it is possible to compute a per capita residential water use number using the Water Plan urban residential water use values and populations, with differing results from the *20X2020 Water Conservation Plan* values.

Since 1980 the population in California has increased by more than 13 million while per capita use has decreased by over 23 gallons per capita day (gpcd) as shown in Figure 2-9. Implementation of water use efficiency measures (water conservation) has led to these reductions. Some urban areas have been more successful in implementing these measures, as case studies illustrate below.

Figure 2-9
California Urban Water Use and Population, 1965-2005
Source: DWR, 1968, 1973, 1983, 1994; DWR et al., 2010



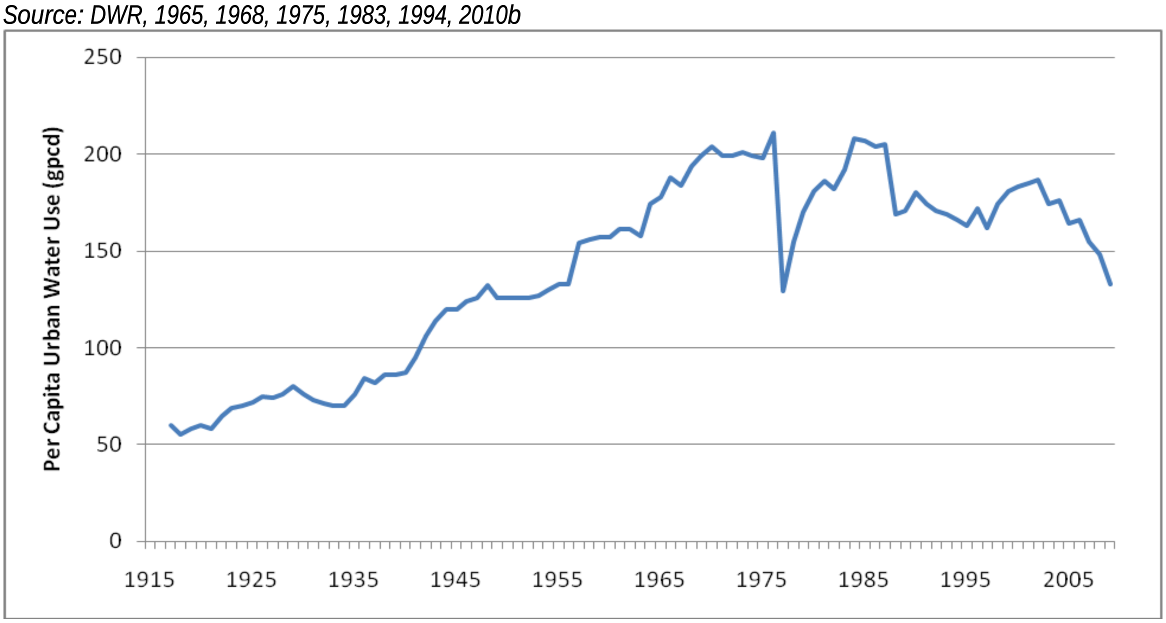
As urban areas in California continue to grow, in addition to water supply development, improved water efficiency (water conservation) will be required to continue to reduce per capita water use and meet water demands. Water efficiency measures implemented in California are based on Best Management Practices (BMPs) set-up by the California Urban Water Conservation Council as outlined in Table 2-1. These BMPs have historically been implemented by water agencies on a voluntary basis; however, some of these are now mandatory due to recent state legislation and water code changes. These changes have included requirements for metering, landscape irrigation ordinances, high efficiency appliances, and a required 20 percent water savings by 2020 in California.

In the future, the most significant water use reductions could come from the implementation of outdoor landscape and irrigation efficiency measures. Outdoor use comprises up to 70 percent of urban household water use (SAWPA, 2009). Installation of “Smart” irrigation controllers, turf reduction programs, and planting of drought tolerant plants are all effective measures to reduce outdoor use. Another significant source of water future water savings could come from requirements for high efficiency appliance and fixtures as toilets and clothes washers account for almost half of indoor urban household water use (SAWPA, 2009).

Case Study: EBMUD Water Use

Water use records for the East Bay Municipal Utilities District (EBMUD) demonstrate the per capita water use trends common in California cities over the last century. Increases in per capita water use through the 1970s were driven by advances in technology and overall living standards. Indoor plumbing, appliances such as dishwashers and washing machines, backyard swimming pools, and larger yards in suburban areas all contributed to increases in per capita water use. The overall water use trends for the EBMUD mirror these developments, as shown in Figure 2-10. The sharp decline in water use in 1977 was a result of water conservation and other water management actions that were put in place during the 1976-1977 drought. Water use also dropped during the 1987-1992 drought due to water management actions. In recent years, water use rates have declined due to implementation of tiered rate structuring, designed to encourage water conservation during the drought conditions experienced during 2007-2009.

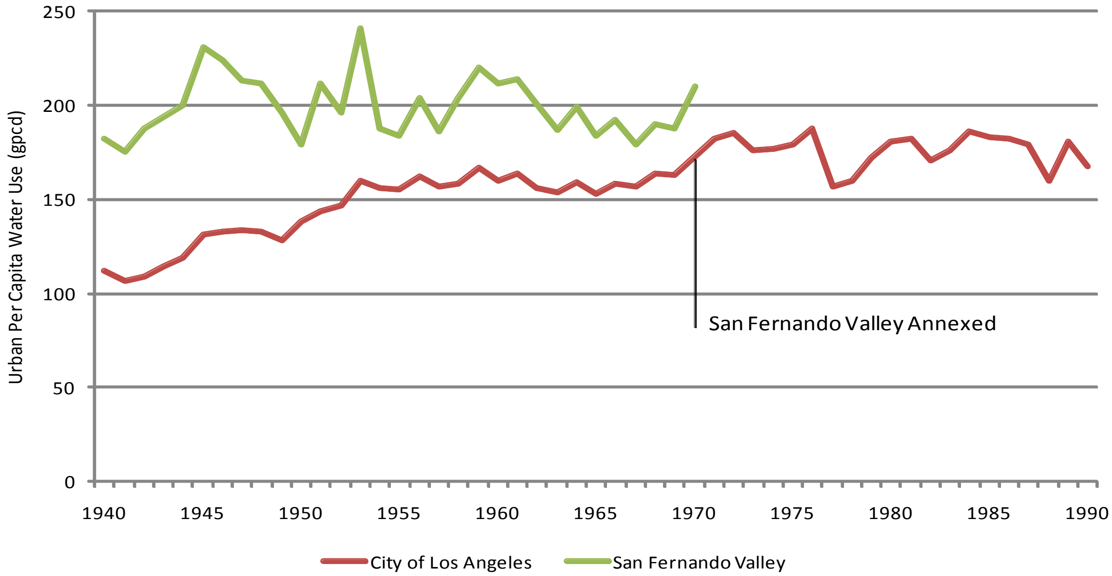
Figure 2-10
East Bay Municipal Utilities District
Urban Water Use (per capita), 1917-2009
Source: DWR, 1965, 1968, 1975, 1983, 1994, 2010b



Case Study: Water Use in Los Angeles

The City of Los Angeles began conserving water over 100 years ago, and water use records demonstrate the effectiveness of these efforts despite advances in living standards. Water conservation began in Los Angeles in the 1890s when William Mulholland led efforts in 1889 to install meters in the city of Los Angeles, decreasing per capita water use from 306 to 200 gallons per day (LADWP, 2010). Since that time, water conservation has been an integral part of water management for the city. According to a National Water Research Institute (NWRI) study, the population of Los Angeles grew 33 percent in the 30 years from 1975 to 2005 without an increase in total water use. During the 1990s alone, Los Angeles County added 1 million residents without increasing total water use (NWRI, 2007). The City of Los Angeles Integrated Plan for the Wastewater Program estimated that water use averaged 178 gpcd from 1971 to 1990, as illustrated by Figure 2-11, and since then has decreased to 147 gpcd due to water conservation efforts. The city estimates that future water conservation measures can decrease per capita water demand by 2 percent to 144 gpcd by the year 2050 (City of Los Angeles, 2000).

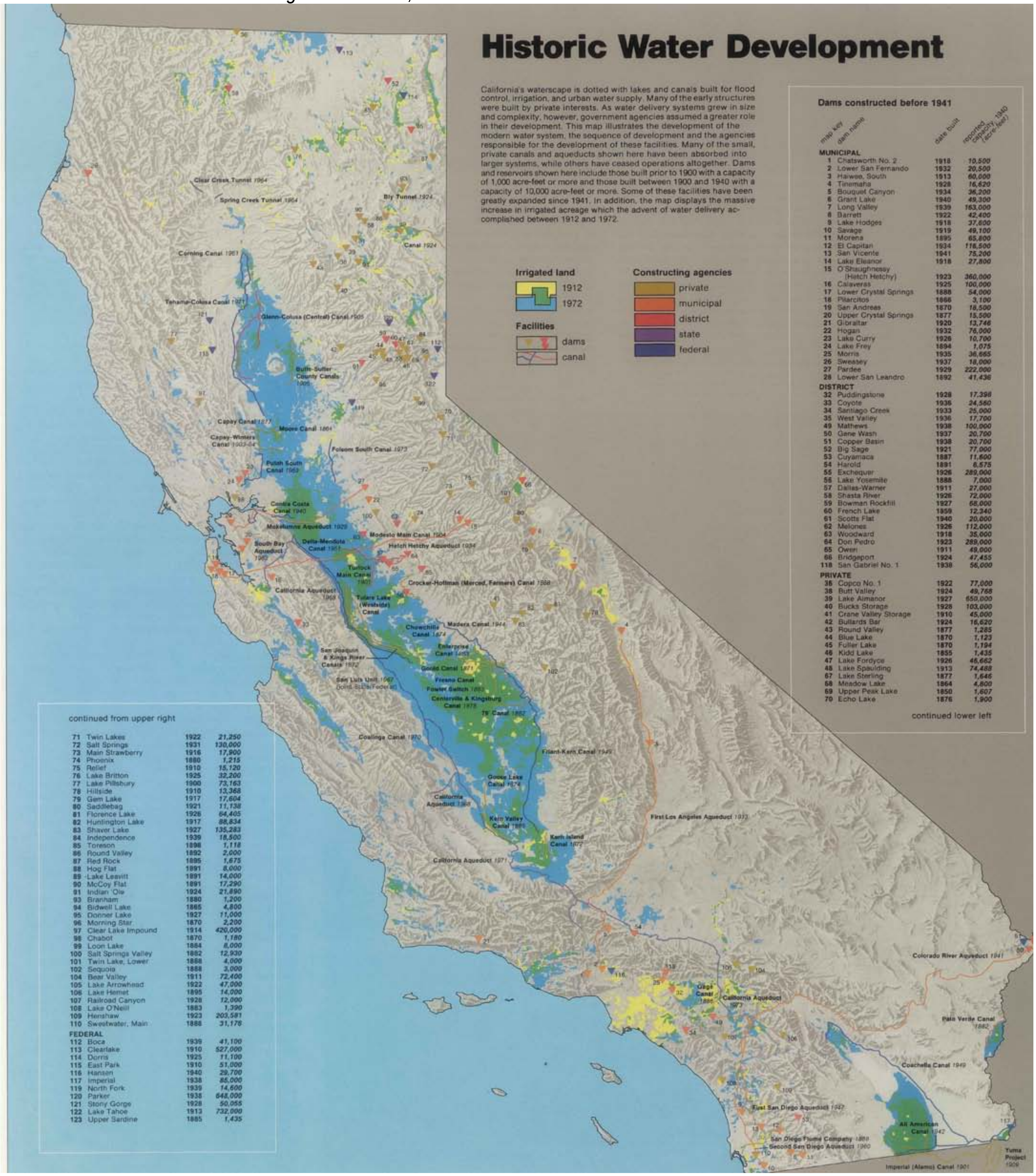
Figure 2-11
Los Angeles Department of Water and Power Urban Water Use (per capita), 1940-1990
Source: DWR, 1968, 1975, 1983, 1994



Agricultural Water Use

California is one of the most productive agricultural regions in the world. There are over 88,000 farms in the state that generate over $100 billion in economic activity related to agriculture (DWR, 2009). California agriculture is dependent on market demands and water availability and is not generally subsistence farming (DWR, 2009). Agriculture in California has developed in conjunction with major water resources projects. This increase was most significant in the Central Valley where the State Water Project and Central Valley Project enabled farming to expand. This is evident in Figure 2-12 where the yellow (1912), green (between 1912 and 1972) and blue (1972) shading shows the massive expansion of land put into production between 1912 and 1972 (Governor's Office of Planning and Research, 1978). Irrigated acreage statewide increased by more than 400 percent between the 1850s and 1990s (Olmstead and Rhode, 2004).

[1]Figure 2-12
Development of Agriculture and Municipal Water Supplies in California
Source: Governor's Office of Planning and Research,1978

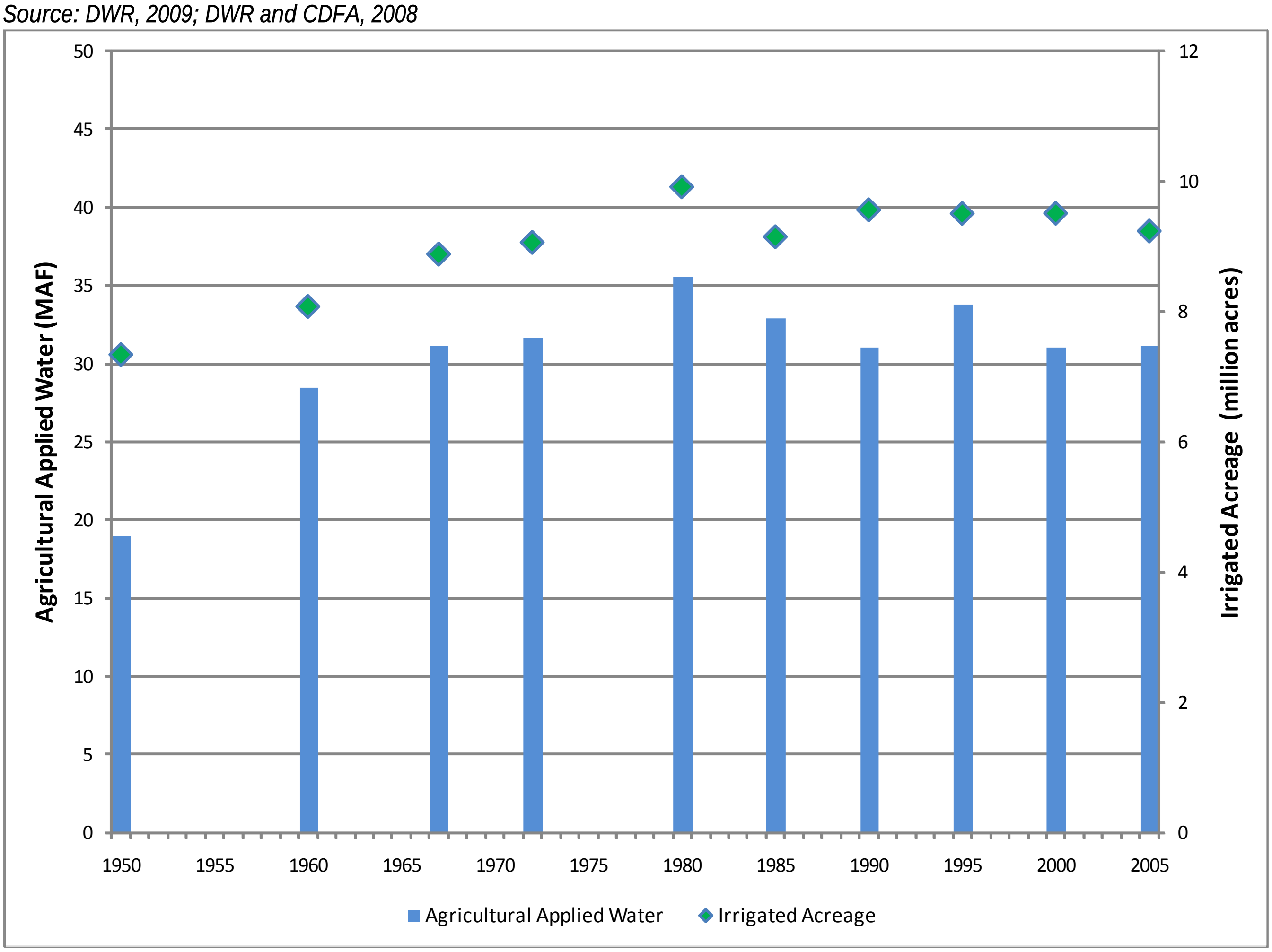


Since the 1970s, agricultural water usage has varied between 38 million acre feet and 42 million acre feet per year statewide due to decreasing crop acreage, crop changes, water management, and better irrigation systems. For the last 20 years, this usage has been at the lower end of the range, as is shown in Figure 2-13. Between 1972 and 2002, the most significant change in water use occurred from changes in crop planting and water management, including (DWR, 2009):

- A reduction from 67 to 42 percent in the amount of field crop planted
- A reduction of 31 percent in the amount of surface irrigation
- An increase from 6 to 16 percent in vineyard production
- An increase from 15 to 31 percent in orchard production
- A 33 percent increase in low-volume (drip) irrigation

Also, land conversion from agricultural to urban use, fallowing , or ecosystem restoration has occurred in Southern California (over 119,000 acres) and portions of the Central Valley (631,000 acres), further reducing agricultural water use.

Figure 2-13
Agricultural Water Use and Irrigated Acreage in California
Source: DWR, 2009; DWR and CDFA, 2008



Water to Meet Environmental Requirements

In the California Water Plan, environmental water use includes instream flows, Wild and Scenic River flows, required Delta outflow, and flows to state and federal wildlife refuges and other managed wetlands. The Water Plan used the "environmental use" category to account for these flows in the water balance. Some of this environmental water is reused by agricultural and urban water users downstream.

Water supplies in California have not always been dedicated to environmental uses. Over time, California has lost over 90 percent of its natural wetlands, and natural flow patterns in a majority of the state's rivers were regulated for flood control or water supply. Ecosystems in many areas of the state have declined due to invasive species, water quality impairments, watershed operations, lack of suitable habitat, and other issues. As Californians identified environmental needs, regulators and water managers responded. For example, in 1993, the Central Valley Project Improvement Act (CVPIA) was passed, which dedicated a portion of the yield of the CVP to protect, restore, and enhance fish and wildlife habitats in the Central Valley and Trinity River Basins. A portion of the water project yield was then allocated to environmental uses instead of delivering this water to agricultural and urban uses. A number of other flow and water quality standards have also been set, including seasonal instream flow requirements to support migrating fish and water quality targets to support fish life cycles.

Recent Bay-Delta flow requirements are contained in the 2006 Bay-Delta Plan and in Decision 1641 (D-1641). In these plans, Delta outflow requirements generally take two basic forms based on water year type and season:

- Specific numerical Delta outflow requirements
- Position of "X2", an expression of a distance from the Golden Gate Bridge to a particular salinity condition[1]

Following implementation of D-1641, salmonid and Delta smelt populations in the Delta watershed continued to decline. These declines have led to issuance of biological opinions starting in the early 1990s. The requirements also have been modified by judicial decisions and additional restrictions. Recently two biological opinions were issued that provided for improved habitat conditions in the Delta and the Delta watershed.

- On December 15, 2008, the United States Fish and Wildlife Service issued a biological opinion on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the CVP and SWP. The Reasonable and Prudent Alternative (RPA) applies to delta smelt and focuses primarily on managing flow regimes to reduce entrainment of delta smelt, the extent of suitable water conditions in the Delta, and on habitat restoration.
- On June 4, 2009, the National Marine Fisheries Service issued its Biological and Conference Opinion on the OCAP, which provides RPA actions to protect winter-run and spring-run Chinook salmon, Central Valley steelhead, green sturgeon, and killer whales from water project effects in the Delta and in upstream areas. The RPA addresses actions related to flow and temperature management, gravel augmentation, fish passage and reintroduction, gate operations and installation, fish screen funding, floodplain and habitat restoration, hatchery management, export restrictions, CVP and SWP fish collection facility modifications, adaptive management, monitoring and reporting, and other actions.

Both opinions are the subject of ongoing litigation, which creates uncertainty about their implementation and about the reliability of water supplies from the Delta.

[1] The horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical saline units (psu).

In 2009, the Delta Reform Act required the State Water Resources Control Board (SWRCB) to develop flow criteria for the Delta ecosystem and the Department of Fish and Game (DFG) to identify quantifiable biological objectives and flow criteria for at-risk species in the Delta. These reports were required in part to inform the planning processes of the Delta Plan and the Bay Delta Conservation Plan (BDCP).

- In August 2010, the SWRCB completed a report identifying flow criteria for the Delta ecosystem. The report includes the volume, timing, and quality of flow for the protection of public trust resources under different existing hydrologic conditions. Although narrow in scope, the report contains a summary of the specific flow needs for certain species based on the most recent and available science. The report concluded that there is sufficient scientific information to support the need for increased flows to protect public trust resources.
- In September 2010, DFG completed a draft report identifying quantifiable biological objectives and flow criteria for aquatic and terrestrial species of concern dependent on the Delta. To date, DFG has identified 21 streams that need instream flow objectives set and another 22 streams that need to be investigated in the future. These identified steams are listed in Table 2-3. A number of these stream segments are located within the Delta watershed, and meeting these objectives could impact water availability.

The results of these flow criteria studies are to be used to inform ongoing programs, including development of the Delta Plan. The flow criteria cannot be used solely by the SWRCB to develop overall flow criteria for Delta and the tributaries without consideration for flow needs for other beneficial uses, including water supplies and recreation.

Table 2-1
Department of Fish and Game List of Streams for Instream Flow Studies

Streams That Require Objectives Now		Streams Where Future Studies Are Needed	
Stream	**County**	**Stream**	**County**
Carmel River	Monterey	Butte Creek	Butte
Redwood Creek	Marin	Toulumne River (below La Grange Dam)	Stanislaus
Brush Creek	Mendocino	San Gregorio Creek (lower)	San Mateo
Lower American River	Sacramento	North Fork of Mavarro River	Mendocino
Lagunitas Creek	Marin	Big Sur River	Monterey
Lake Tahoe Basin	Multiple	Santa Maria River	Santa Barbara
North Fork Feather River	Multiple	Redwood Creek (tributary to Maacama)	Sonoma
Upper West Fork San Gabriel River	Los Angeles	Bear River (Below Camp Far West)	Placer and Nevada
Yuba River	Yuba	Shasta River	Siskiyou
Rush Creek	Mono	Carmel River	Monterey
Lower Mokelumne Rive	San Joaquin	Santa Margarita River	Riverside
Parker Creek	Mono	Merced River (below Crocker-Huffman Dam)	Merced
South Parker Creek	Mono	Redwood Creek (tributary to Napa River)	Napa
Walker Creek	Mono	Scott River	Siskiyou
Upper Owens River	Mono	Mattole River (near Whiethorn)	Humboldt
Lee Vining Creek	Mono	Dry Creek (tributary to Napa River)	Napa
Merced River	Merced	Deer Creek (tributary to Yuba River)	Nevada
Scott Creek	Santa Cruz	Mojave River	Riverside
Mill Creek	Mono	Carpentaria Creek	Santa Barbara
Truckee River Basin	Multiple	Santa Ana River	Riverside and San Bernardino
Battle Creek	Shasta and Tehama	Middle Fork Feather River	Plumas
		Dos Pueblos Creek	Santa Barbara

Total Water Use in California

A majority of the water used in California is within the Delta watershed and areas that use water exported from the Delta, as shown in Figure 2-14. Southern California has the largest population as well as urban use in the state. Agricultural use is highest in the Sacramento River, San Joaquin, and Tulare Lake areas. Flow restrictions to meet environmental requirements are highest in the North Coast, Sacramento River, San Joaquin, and Tulare Lake areas. Figure 2-15 shows the changes in water use distribution due to climate changes based on a wet (1998), normal (2000), and dry year (2001). Urban (2 percent change) and agricultural (11 percent change) use increases and environmental water (13 percent change) decreases in drier years. Environmental (28 percent decrease) and agricultural (23 percent increase) use have the largest swing between wet and dry years.

Figure 2-14
Total Water Use in California
Source: DWR, 2009

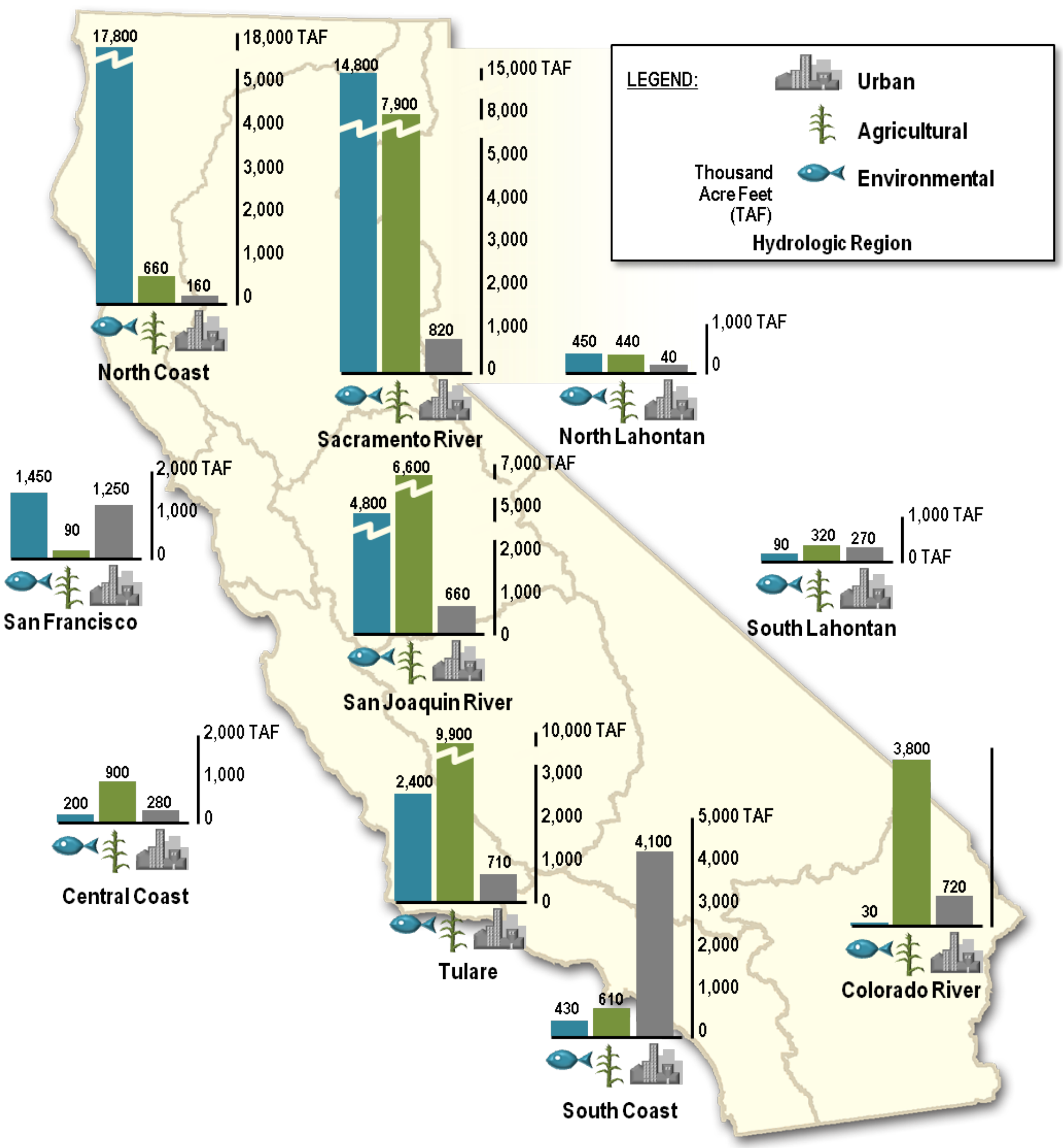
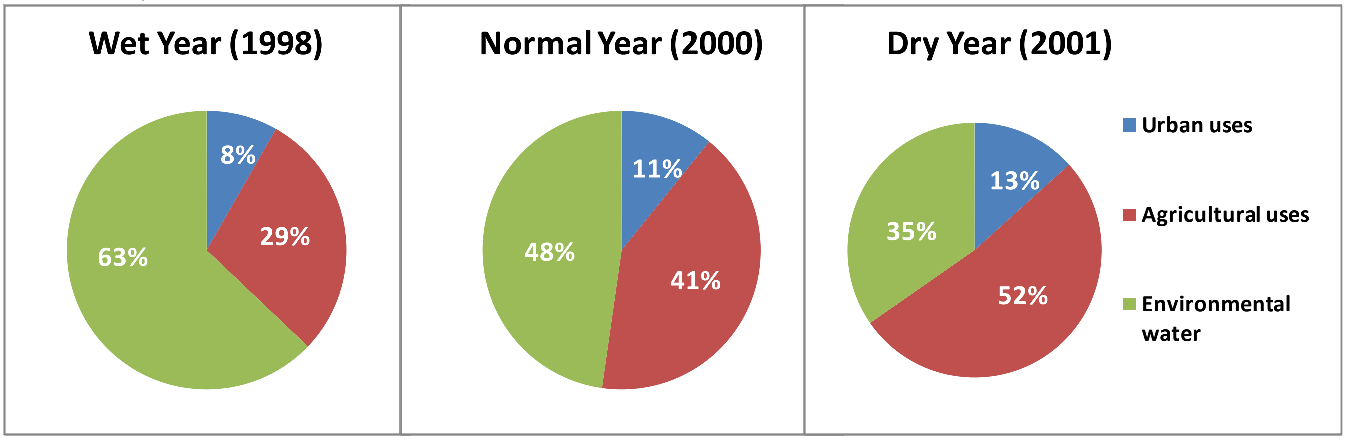


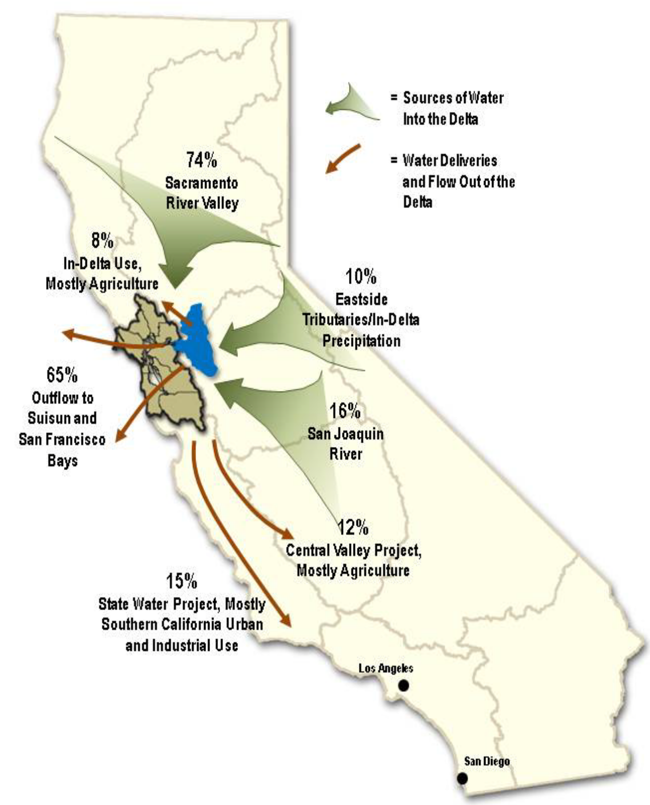
Figure 2-15
Total Water Use in California
Source: DWR, 2005



Section 3
Water Supply Development

This section of the white paper will discuss water supply development and management in California to meet changing water needs. Water resources were developed by first using local water resources. Development included groundwater pumping, local stream runoff and river diversions, and local reservoirs. These resources were adequate to allow population growth until the 1920s and 1930s when groundwater overdrafting and water scarcity challenged the water-poor areas of California. Major water supply projects were developed, including reservoirs constructed to impound stream and flood flows as well as aqueducts and canals to move water to areas where water was insufficient to meet demands. In the 1970s and 1980s, water conservation and water recycling were implemented in some areas of the state to fully utilize existing water resources. Groundwater recharge and conjunctive use projects also were implemented to replenish and manage groundwater resources. Brackish or saline water supplies (including groundwater, surface water, and seawater) have also been developed to help meet water demands. Appendix A summarizes major events in water development in California. The following section will provide an overview of how Delta water is used and its role California water development.

Figure 3-1
Water Movement through the Delta
Source: LAO, 2008



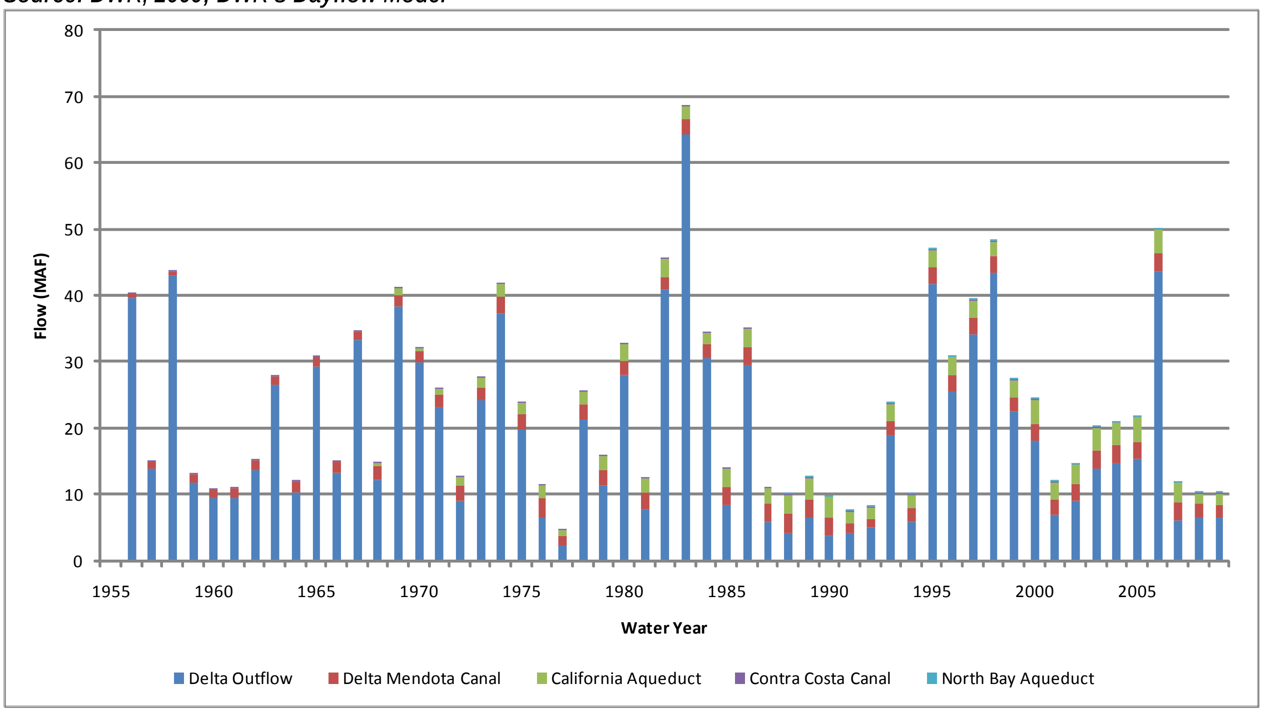
Sacramento – San Joaquin Delta

The Delta is at the center of water in California. Water from the Sacramento and San Joaquin rivers flows into the Delta. Runoff into the Delta averages about 21 million acre-feet per year, which is 42 percent of the surface water in California (DWR, 2009). This is the reason a majority of the state relies on the Delta for water.

Figure 3-1 shows water movement into and out of the Delta. The natural Delta system consists of water inflows from upstream tributaries and outflow to the Suisun and San Francisco Bay. Over time this pattern has been changed by exporting water to areas where local supplies cannot support existing water needs. Water is moved from the water-rich Delta to other areas of the state that may not be adequately supported by local supplies. These areas include densely populated areas (i.e., San Francisco and southern California) and agricultural areas (i.e., San Joaquin Valley and Tulare Lake). The next subsections of this white paper will discuss major water projects that have been developed to move Delta water to users.

Figure 3-2 shows the amount of water that is exported and flows annually from the Delta. Water from the Delta watershed is used by in-Delta and upstream diverters, provided to meet flow requirements for ecosystem health and to prevent salinity intrusion, and exported to southern and central California to supply urban and agricultural uses. This runoff supplies one-quarter of the state's urban water supply and is a major source to two-thirds of California's population (DWR, 2009). Runoff to the Delta also supplies water to over 700 million acres of irrigated land (Reclamation, 2009b). Figure 3-2 also shows the variability in Delta exports based on water availability in the system. The reduction of flow from the droughts of 1959-61, 1976-77, 1987-92, and 2007-09 (DWR, 2010) has impacted water availability from the Delta. These flow reductions impact water supply available for urban and agricultural uses.

Figure 3-2
Delta Exports and Outflows
Source: DWR, 2009; DWR's Dayflow Model



Delta Water Quality

Water quality in the Delta, especially salinity, is impacted by climatic conditions (freshwater inflows and drought cycles), upstream and in-Delta uses, tidal influences, and in-Delta and export diversions and operations. Water quality is better in the north Delta than in the central and southern Delta. Specific water quality issues within the Delta include salinity, Total Organic Carbon (TOC), turbidity, bromide, pesticides, mercury pathogens, ammonia, and dissolved oxygen. Salinity has been the most important of these concerns because it can impair the use of water by municipal, industrial, and agricultural users and aquatic organisms. Specific factors that may cause salinity to exceed water quality objectives in the Delta include:

- Seawater intrusion from the Pacific Ocean and San Francisco Bay during high tides and relatively low fresh water outflows in the western Delta
- Salts from San Joaquin River outflows originating in agricultural return flows and from municipalities as well as other sources in the southern Delta
- In-Delta irrigation return flows that result in localized increases in salinity in dead-end sloughs and low-capacity channels (null zones) at Old River between Sugar Cut and the CVP intake, Middle River between Victoria canal and Old River, and the San Joaquin River between the head of Old River and the City of Stockton (SWRCB, 2010)

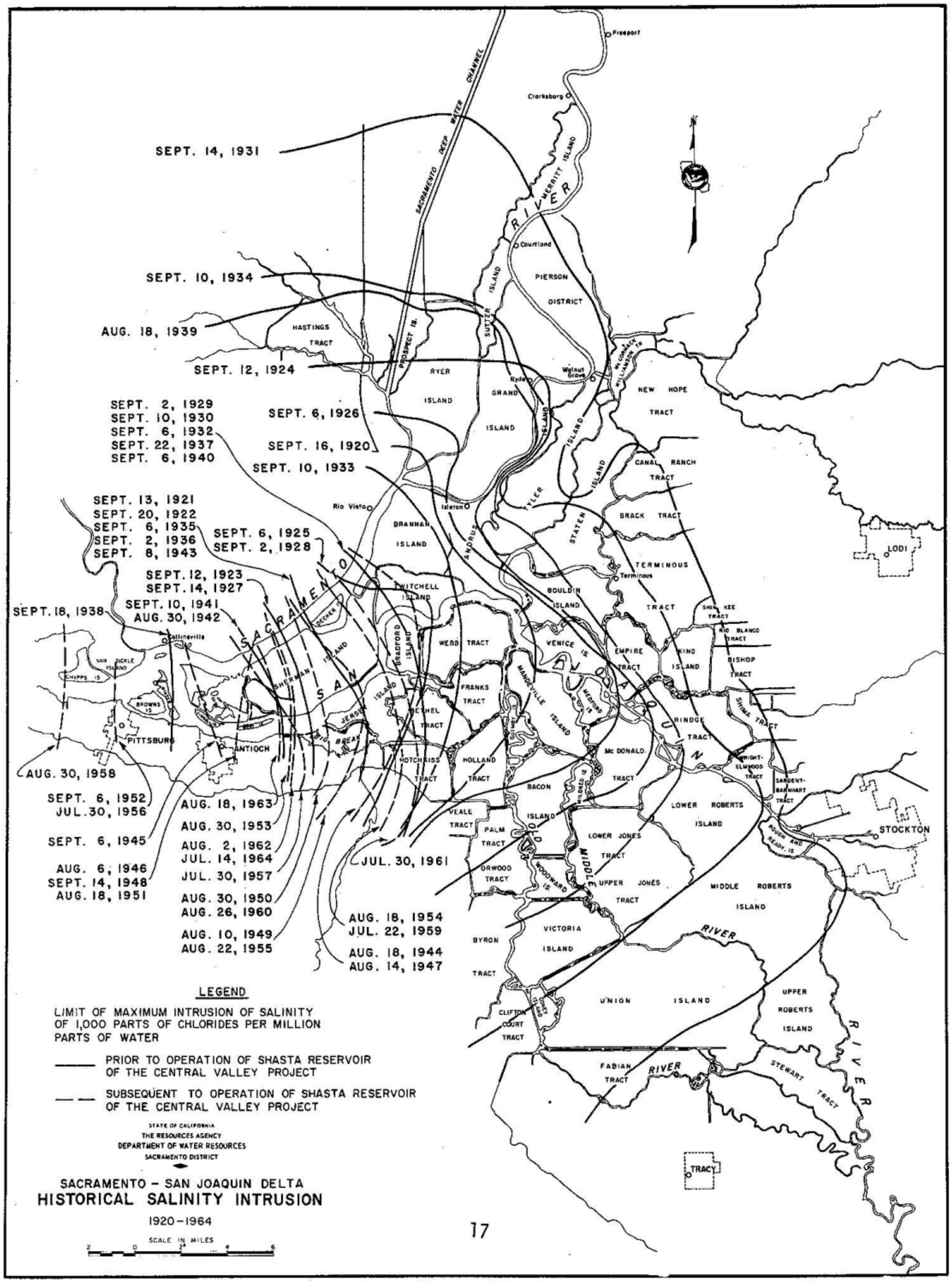
Salinity in the western Delta depends on freshwater inflows from the Sacramento and San Joaquin rivers, wind movement from the Golden Gate, and daily tidal actions. Early reports from a Spanish expedition in 1775 and a United States expedition in 1841 indicated that fresh water was located near the confluence of the Sacramento and San Joaquin rivers, possibly near New York Slough (approximately near the Pittsburg-Antioch city border). Antioch established a freshwater intake in the 1860s on the San Joaquin River near the present State Highway 12 Bridge. Numerous cities and industries between Crockett and Antioch established freshwater intakes in the late 1800s. However, some of these intakes were abandoned due to high salinity and water pollution from upstream wastewater discharges, including the City of Pittsburg intake that was replaced with groundwater wells in the early 1920s. However, there were indications that brackish water occurred near the confluence of the two rivers during dry periods (DWR, 1931). The California & Hawaiian Sugar Refining Corporation hauled water to the Crockett plant from the Delta until 1920 when water was hauled from Marin County. The summary of the records from the refinery indicate that freshwater was obtained near the river confluence in most years except during late summer or droughts between 1908 and 1920. The summary of the records indicate that Suisun Bay was characterized as fresh in most years between 1908 and 1929 except during droughts.

Records indicated that the combined Sacramento and San Joaquin rivers average annual flow between 1871 and 1929 was about 31,000,000 acre-feet per year (DWR, 1931). However, the average from 1909 to 1929 was 24,000,000 acre-feet per year and the average between 1919 and 1929 was 19,000,000 acre-feet per year. The reduction in flow was partially caused by reduction in average rainfall from numerous wet years between 1871 to 1917 as compared to the dry years in the 1918 through 1929 period, which included the beginning of the longest drought of historical record in California (1927-1934). The inflows also were reduced due to increased irrigation in the upper watersheds. By 1929, over 1,317,000 acres were irrigated in the watershed and between 1915 and 1920 the irrigated acreage increased by 67,000 acres per year due to the development of rice that used water between April and October when the salt water intrusion was the most severe. During this same period, reservoir capacity in the watershed increased from 350,000 acre-feet in 1910 to more than 4,000,000 acre-feet in 1929. Historic salinity intrusion in the Delta is shown in Figure 3-3.

The state initiated the first Delta salinity investigation in 1916. The City of Antioch filed a lawsuit in 1920 against water users in the upper watershed based upon reduction in water quality of their water right. The State Supreme Court ruled against the City of Antioch because the court indicated that the water right on the San Joaquin River was for diversion and could not be used to require upstream diverters to leave enough water in the river to reduce salt water intrusion below the point of diversion. However, the litigation brought attention to the Delta salinity issue and further investigations were completed in the 1920s, 1930s, 1940s, 1950s, and 1960s. In the 1950s and 1960s, the state investigated establishment of salt water barriers on the Sacramento River near Steamboat Slough and Walnut Grove, on Cache and Lindsay sloughs, and possibly barriers on the San Joaquin River near Paradise Cut (DWR, 1957).

Following completion of the SWP, DWR signed agreements with North Delta Water Agency, City of Antioch, and Byron-Bethany Irrigation District to maintain freshwater salinity concentrations in the western and northern Delta under specific provisions. Since 1967, the salinity limitations have been met except for the agreement with the City of Antioch. When salinity at the Antioch water supply intake is too high, the city purchases water from Contra Costa Water District that uses upstream water intakes and the DWR partially reimburses the city for these purchases.

Figure 3-3
Historical Salinity Intrusion in the Sacramento-San Joaquin Delta
Source: Jackson and Patterson, 1977



Salinity has continued to increase over the past 100 years as additional water has been diverted upstream of the Delta and within the Delta. DWR and the U.S. Bureau of Reclamation (Reclamation) model projections indicate that salinity intrusion will continue to increase with sea level rise. Currently, the SWRCB is working to update salinity requirements in the San Joaquin Valley. The focus of this effort is to reduce salinity inflows into the Delta as well as protect south Delta agricultural uses. Salinity from the San Joaquin River occurs due to upstream water development (i.e., reduced flows), agricultural land use, irrigation return flows, and wastewater discharges (Central Valley Regional Water Quality Control Board, 2003). Upstream water development including dams, canals, reservoirs, and diversions reduce the historic flow in the river. This also is impacted by seasonal inflows of agricultural return flows, which increase salinity in the river. Agricultural practices, subsurface accretions from groundwater, and imported water are sources of salinity. Salinity will continue to be an issue in the future and could result in the need for additional changes in CVP and SWP operations for ecosystem needs as well as construction of treatment plants to reduce concentrations for water users.

Surface Water

Surface water has been used to meet water demands in California since it was first settled. Initially local water supplies were developed by diverting flow and damming rivers. This was sufficient to meet demands until the 1920s and 1930s when demand for irrigated crops and migration into southern California increased following completion of the transcontinental railroad. Between the 1920s and 1970s, a number of regional and statewide interbasin transfers were developed to meet expanding water needs in the state as population and agriculture expanded. These transfers included reservoirs as well as major aqueduct or canal systems. The Toulumne and Mokelumne Aqueducts, Central Valley Project, State Water Project, Los Angeles Aqueduct, and Colorado River Aqueduct were all developed during this timeframe.

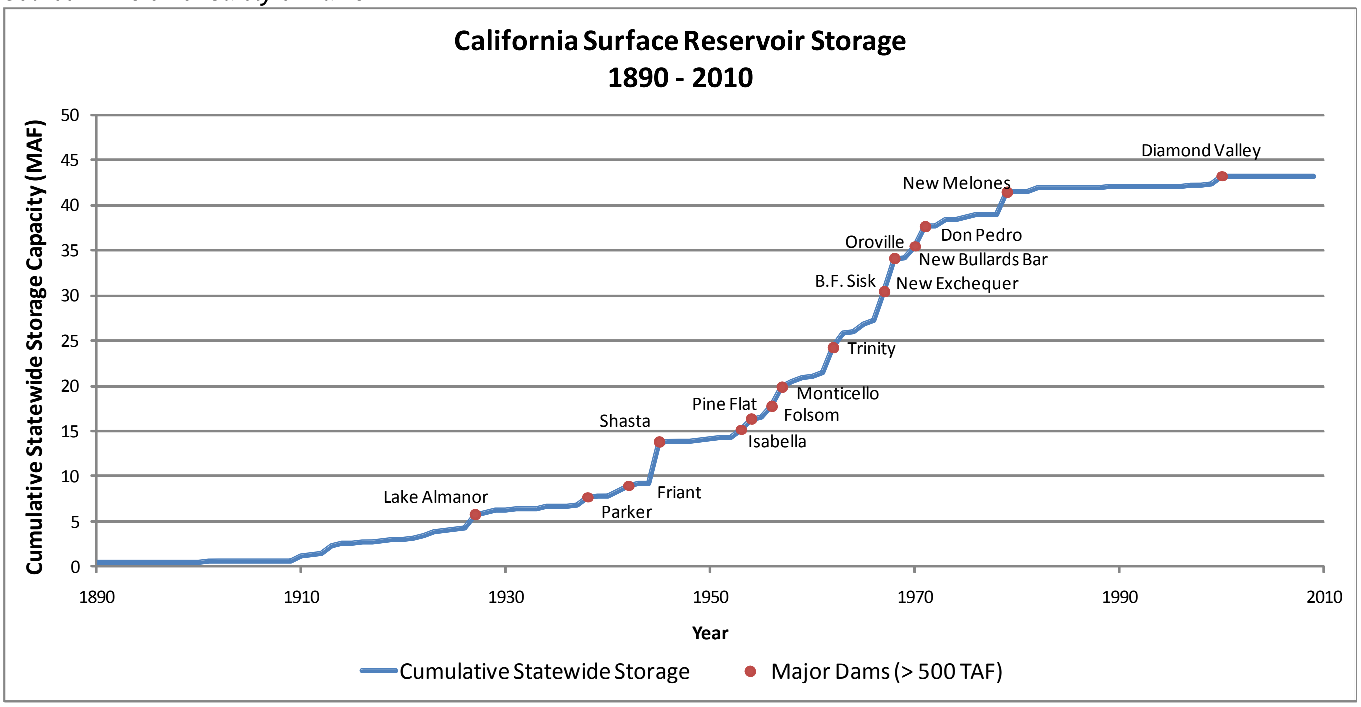
Surface Water Storage

Local water supplies have been developed on a majority of rivers in California by diverting or impounding water. There is some evidence that Native Americans modified overflow basins on a local basis in the Owens and Imperial valleys to expand areas that naturally flooded for the purpose of expanding areas with useful native vegetation (OPR, 1979 - California Water Plan). Spanish missionaries and settlers built the Zanja Madre to convey water from the Porciuncula River to the Pueblo de Los Angeles and adjacent irrigated lands in the 1770s. During the same time, a 12-foot-high dam and a 245-foot-high dam were constructed on the San Diego River along with over 6 miles of canals to convey water to Mission San Diego. In southern California agencies developed water on the Los Angeles, San Gabriel, Santa Ana, San Dieguito, Sweetwater, and Otay Rivers and their tributaries. Along the Central Coast, water supply was developed on the Pajaro, Santa Maria, and Santa Ynez rivers and their tributaries. In northern California, local water supply was developed on the Sacramento and San Joaquin rivers and Coyote, Putah, San Antonio, and San Leandro creeks.

Reservoirs and dams have been constructed since the late 1800s by local, state, federal, and private entities, such as power companies, for water impoundment, flood control, and hydroelectric power generation. Figure 3-4 shows the growth in reservoir capacity across the state over time. A majority of these reservoirs were developed after the 1920s as part of regional or statewide interbasin transfer projects. There are approximately 1,400 dams in the state of California, 85 percent of which are regulated by the State of California and the remainder by the federal government. Of the 1,400 dams, 913 have a storage capacity less than 1,000 acre-feet, 328 have capacity between 1,000 and 9,000 acre-feet, and approximately 204 have a capacity more than 10,000 acre-feet.

In the Delta watershed and use areas, there are over 178 major dams (i.e., capacity over 10,000 acre-feet) with a total capacity of over 37 million acre-feet. Over half of this capacity is stored in the ten largest reservoirs (Shasta, Oroville, Trinity, New Melones, B.F. Sisk, Don Pedro, Monticello, Lake Almanor, New Exchequer, and Pine Flat). Lake Shasta and Lake Oroville are the two largest reservoirs with capacities of 4,552,000 and 3,537,577 acre-feet, respectively. A listing of dams with storage capacities greater than 10,000 acre-feet that serve water users from the Delta watershed is presented in Table B-1 in Appendix B DWR, 2010c).

Figure 3-4
Development of Surface Water Storage in California
Source: Division of Safety of Dams



Major Interbasin Transfers

A number of major interbasin transfer projects have been developed since the 1920s in California. These were constructed to convey water from the higher elevations to irrigated lands and communities in the Central Valley and coastal areas of central and southern California. These projects consisted of major reservoirs and aqueduct systems and were designed as a permanent solution to water supply issues in California. In recent years due to ecosystem requirements, biological opinions, court decisions and droughts, these transfers have been reduced, which impacted water supply availability in areas reliant on transferred water. Major interbasin transfer projects discussed in this white paper include:

- Mokelumne/Tuolumne Transfers, including the Mokelumne and Hetch Hetchy Aqueducts
- Central Valley Project and State Water Project
- Southern California Aqueducts, including the Los Angeles and Colorado River Aqueducts

Mokelumne/Tuolumne Transfers

One of the first projects to import water from a non-adjacent watershed was the City of San Francisco’s Hetch Hetchy project. Following the discovery of gold, San Francisco’s population grew from 400 residents in 1848 to over 150,000 in the 1870s. Private water companies developed water rights in areas near the city. The cost of water increased as conveyance and storage systems were expanded. By 1900, local water supplies were fully developed, and a portion of the water supply was imported by barges from Marin County (Hudley, 2001). As the price of water service increased, the city initiated studies in 1882 to consider developing the Hetch Hetchy project. In 1890, Congress included Hetch Hetchy and Yosemite valleys in the newly established Yosemite National Park. In 1903, the city applied to the federal Interior Department to develop water storage in Hetch Hetchy Valley. The permit was denied in 1903 and 1905. In 1913, the federal government adopted the Raker Act, which allowed construction of the Hetch Hetchy project on federal land. The project was completed by 1934.

A similar project was developed by East Bay Municipal Utility District, which was formed in 1923 to serve the eastern portions of the San Francisco Bay Area near the City of Oakland. Water storage was developed on the Mokelumne River. The Pardee Dam and Mokelumne Aqueduct were completed in 1929. Figure 3- 5 provides a system map of the Hetch Hetchy and Mokelumne Aqueducts.

Figure 3-5
Existing San Francisco Bay Area Water Supply Facilities
Source: BAWAC, 2006a

Central Valley Project and State Water Project

During the 1920s, the California state legislature commissioned a series of investigations to further evaluate the Marshall Plan and other concepts to reduce salinity intrusion in the Delta and provide water to areas of the San Joaquin Valley with extreme groundwater overdraft. Most of the alternatives included construction of reservoirs in Northern California and conveyance to the Delta and San Joaquin Valley water users in isolated canals, or by using Delta channels with a cross-Delta channel that would convey water from the Sacramento River near Walnut Grove to the San Joaquin River. In 1930, DWR Bulletin No. 25, “Report to the Legislature of 1931 on State Water Plan,” outlined a statewide water plan that included conservation and water resources facilities development and utilization. The legislature approved the plan in 1941 as the State Water Plan, which included a description of facilities that would eventually be constructed as part of the Central Valley Project (CVP) and State Water Project (SWP). Figure 3-6 shows a map of the CVP and SWP systems.

Central Valley Project

The CVP is the largest surface water storage and delivery system in California, with a geographic scope covering 35 of the state’s 58 counties. The project includes 20 reservoirs, with a combined storage capacity of approximately 11 million acre-feet; 8 power plants and 2 pumping-generating plants, with a combined capacity of approximately 2 million kilowatts; and approximately 500 miles of major canals and aqueducts. Figure 3-6 shows the locations of CVP facilities, rivers that are controlled or affected by the operation of CVP facilities, and the CVP service area.

The CVP delivers water in accordance with requirements of water right settlement and exchange contracts with the CVP, water rights agreements with the CVP, water quality requirements established by the SWRCB, refuge water supplies and fish and wildlife requirements in accordance with the Central Valley Project Improvement Act (CVPIA) (Public Law 102-575), and water service contractors in the Central Valley, Santa Clara Valley, and the San Francisco Bay Area. Fish and wildlife requirements were initially added to the CVP purposes in 1954 when Congress adopted the Grassland Development Act to cooperate with the state to supply water to Grasslands Resource Conservation District for waterfowl cooperation. In 1958, Congress adopted the Fish and Wildlife Coordination Act to integrate U.S. Fish and Wildlife Service (USFWS) conservation programs with federal water resources facilities, to authorize facilities to mitigate CVP-induced damages to fish and wildlife resources, and to require consultation for CVP facilities with USFWS. Table 3-1 provides a timeline of major CVP development milestone.

State Water Project

The State Water Project is the largest state-built, multi-purpose, user-financed water project in the country. The project includes 20 reservoirs, with a combined storage capacity of approximately 5.8 million acre-feet; 6 power plants and 4 pumping-generating plants, with a combined capacity of approximately 2.6 million kilowatts, and approximately 700 miles of major canals and aqueducts. Figure 3-6 shows the locations of SWP facilities.

In 1947, the state began an investigation to consider the next phases of the California Water Plan to meet the state’s anticipated water needs through development of the SWP and to control salinity intrusion in the Delta. In 1953, the state adopted the Abshire-Kelly Salinity Control Barrier Act to evaluate placement of a saltwater barrier near Suisun Bay to protect Delta water users and allow transfer of freshwater from the Sacramento Valley to the San Joaquin Valley. This plan was not adopted primarily because of costs and technical considerations.

Figure 3-6
CVP and SWP Facilities
Source: DWR, 2009

Table 3-1
Major CVP Development Milestones

1933	Central Valley Planning Act	Authorization for Sale of $170 million in Bonds for the construction of Shasta Dam and power plants on the Sacramento River; Friant Dam on the San Joaquin River; power transmission facilities from the Shasta Dam to Tracy; and the Contra Costa, Madera, and Friant-Kern canals
1930-1940s	Great Depression	
1935	Rivers and Harbors Act of 1935	Congress appropriated $20 million in Emergency Relief Appropriation Funds and authorized construction of the CVP by the USACE.
1937	Reauthorization of Rivers and Harbors Act	Construction and operation of the CVP was assigned to Reclamation, and the CVP became subject to reclamation law
1937	Construction of Contra Costa Canal	
1938	Construction of Shasta Dam begins	
1944	Shasta Dam Construction Completed	
	Flood Control Act	Authorization for construction of New Melones Dam and Reservoir on the Stanislaus River by the USACE to alleviate serious flooding problems along the Stanislaus and lower San Joaquin rivers
1945-1949	Friant Dam, and the Madera, Friant-Kern, and Contra Costa canals Construction Completed	
1949	American River Act	Authorized the American River Division of the CVP and provided for the construction of Folsom and Nimbus dams, lakes, and power plants
1950	Reauthorization of American River Act	Reauthorize the entire CVP to include the Sacramento River Division, which includes facilities to divert and deliver water from the Sacramento River to lands in the western Sacramento Valley by the Tehama Colusa Canal
1951	Cross Channel, Tracy Pumping Plant, and Delta-Mendota Canal Construction Completed	Delivery of water to the San Joaquin River Exchange Contractors
1955	Trinity River Division authorized	Authorized storage of water in the Trinity River Basin, transfer of stored water to the Sacramento River Basin, and generation hydroelectric energy
1960	San Luis Unit Authorized	
1961	Federal State Agreement on San Luis Unit construction	
1962	Flood Control Act Reauthorized	New Melones Dam and Reservoir incorporated into CVP Eastside Operations
1965	Auburn-Folsom South Unit Authorized	Authorized to increase the water supply available for irrigation and other beneficial uses in the Central Valley
1967	San Felipe Division Authorized	Authorized to provide water supplies to portions of the Santa Clara and Pajaro valleys from the San Luis Reservoir
1975	Cross Valley Canal Construction Completed	Deliver CVP water to users in the Tulare Lake Region
1979	New Melones Reservoir Construction Completed	

In 1957, DWR's Bulletin No. 3 was published to define the need for the SWP and the facilities to convey water from the Sacramento Valley to water-short areas of California. The report identified that there was urgency to expand the statewide water facilities due to projected population growth to support a balanced economy, major industrial growth, an agricultural industry that supported 6,875,000 acres of irrigated agriculture (approximately 25 percent of all agricultural acreage in the United States), and flood control in Northern California. The study identified a seasonal deficiency of 2,675,000 acre-feet of water in 1950 that had been met with groundwater pumping primarily from overdrafted aquifers.

In 1960, California voters authorized the Burns-Porter Act to construct the initial projects of the SWP, including Oroville Dam and Lake Oroville on the Feather River, the San Luis Dam and Reservoir to be jointly constructed and operated with Reclamation, the North and South Bay aqueducts, and the California Aqueduct, leading to the SWP as it exists today.

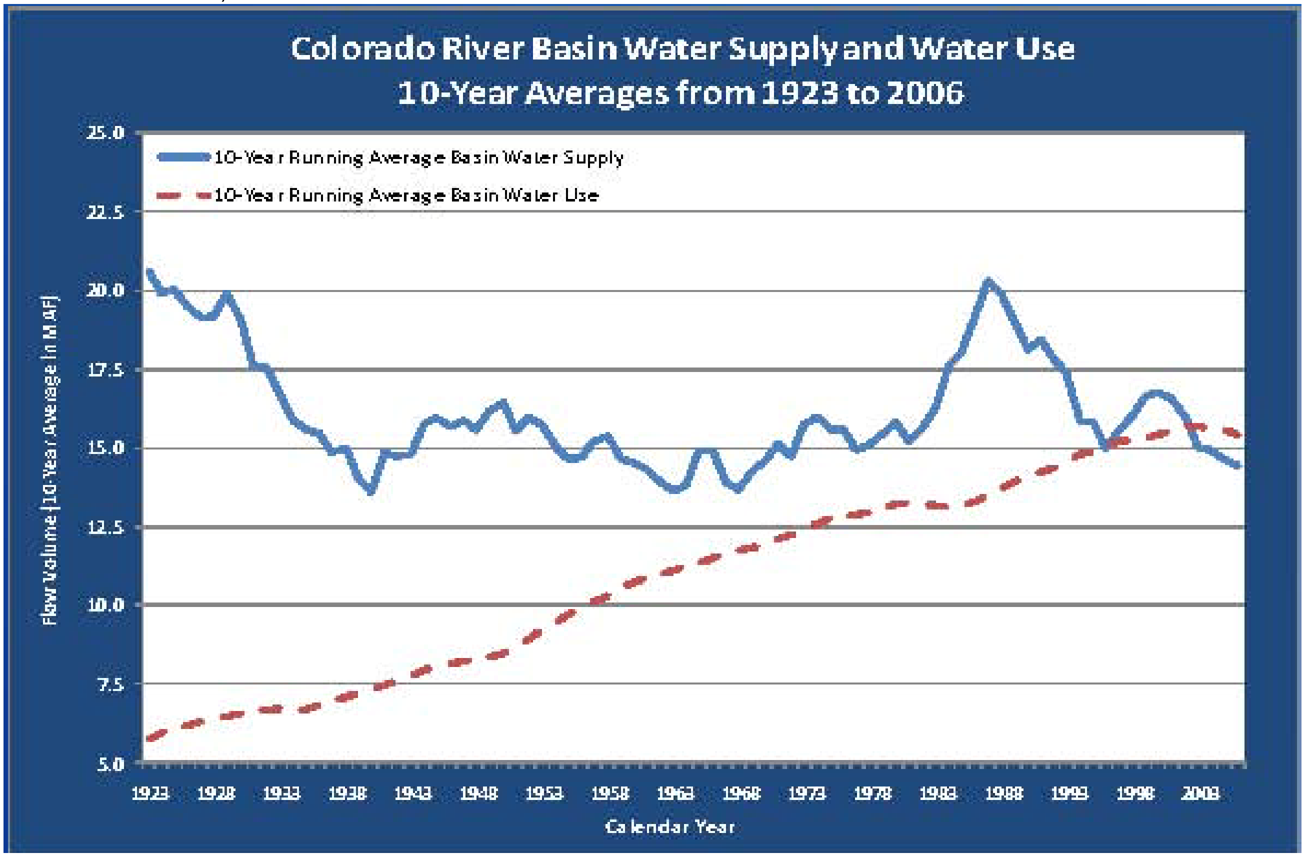
Southern California Aqueducts

The City of Los Angeles diverted water from the Los Angeles River into a system of zanjas (canals), which provided adequate water supply for a population of 9,000 in the 1870s (Mulholland, 2000). These local sources were expanded with new reservoirs and development of groundwater and artesian springs to meet the increasing population of 100,000 by the early 1900s. To meet the projected growth, the city constructed the Los Angeles Owens Aqueduct to Owens Lake in 1913. The aqueduct was extended to Mono Lake in 1941. A second Los Angeles Aqueduct was constructed in the 1960s to perfect (claim) the water rights from Mono Lake and the Owens Valley. In 1983 due to concerns over ecosystem impacts due to water diversion from Mono Lake, the National Audubon Society v. LADWP court decision created the Public Trust doctrine, which allowed the RWQCB to amend and reduce LADWP's existing water rights appropriation in the Owens Valley, which it did in 1994. Since that time, water from the Los Angeles Aqueduct averages between 106,000 acre-feet (dry years) and 256,000 acre-feet (wet year).

Southern California also developed water supplies from the Colorado River. Colorado River water had been delivered to the Imperial Valley since the 1870s. Imperial Irrigation District was organized in 1911 to further develop water diversion from the Colorado River. By the 1920s, substantial water was diverted by numerous states in the Colorado River watershed, and supplies were not sufficient in drier years. In 1922, the Colorado River Compact was signed to allocate water between the seven Colorado River Basin states. In 1928, Congress adopted the Boulder Canyon Project Act to construct Hoover Dam and the All American Canal, which would deliver up to 4.4 million acre-feet per year of water to California. The California Seven Party Agreement of 1931 allocated the Colorado River water supply within California, including the provision of water supplies to Imperial Irrigation District and San Diego. The City and County of San Diego allocation was transferred to Metropolitan Water District of Southern California (Metropolitan) when San Diego joined the regional agency. Construction on the Colorado River Aqueduct was completed in 1941. A Supreme Court Decision (Arizona v. California) in 1963 cut water supplies from the Colorado River in half reducing imported water supplies to the State. This decision limited California rights on the Colorado to 4.4 million acre-feet plus half the surplus water. The Quantification Settlement Agreement (QSA) was reached in 2003, which quantifies the priority of rights on the lower Colorado River as well as establishes a transfer of water conserved from lining the All American Canal from Imperial ID (IID) to San Diego County Water Authority (SDCWA). Water supply reliability continues to be a concern in the Colorado River Basin as water use is increasing while Colorado River flows are generally decreasing (on a ten-year average). Figure 3-7 shows that the long-term trend of water use surpassing flows in the river (as shown on Figure 3-7.)

Figure 3-6 shows the location of both the Los Angeles and Colorado River Aqueducts.

Figure 3-7
Colorado River Supply and Demand
Source: Reclamation, 2010



Groundwater

California uses 20 percent of groundwater extracted in the United States (DWR, 2003). Groundwater provides, on average, about 30 percent of the State's water supply for urban and agricultural uses. Approximately half of all Californians depend on groundwater for part of their water supply. In dry years, groundwater provides over 60 percent of the water supply in some regions of California. Significant groundwater use occurs in the San Joaquin, Tulare Lake, Sacramento Valley, Central Coast, and South Coast regions of California. Over a third of groundwater use in California occurs in the Tulare Lake Basin. Figure 3-8 provides a summary of the groundwater use in each hydrologic region of the state.

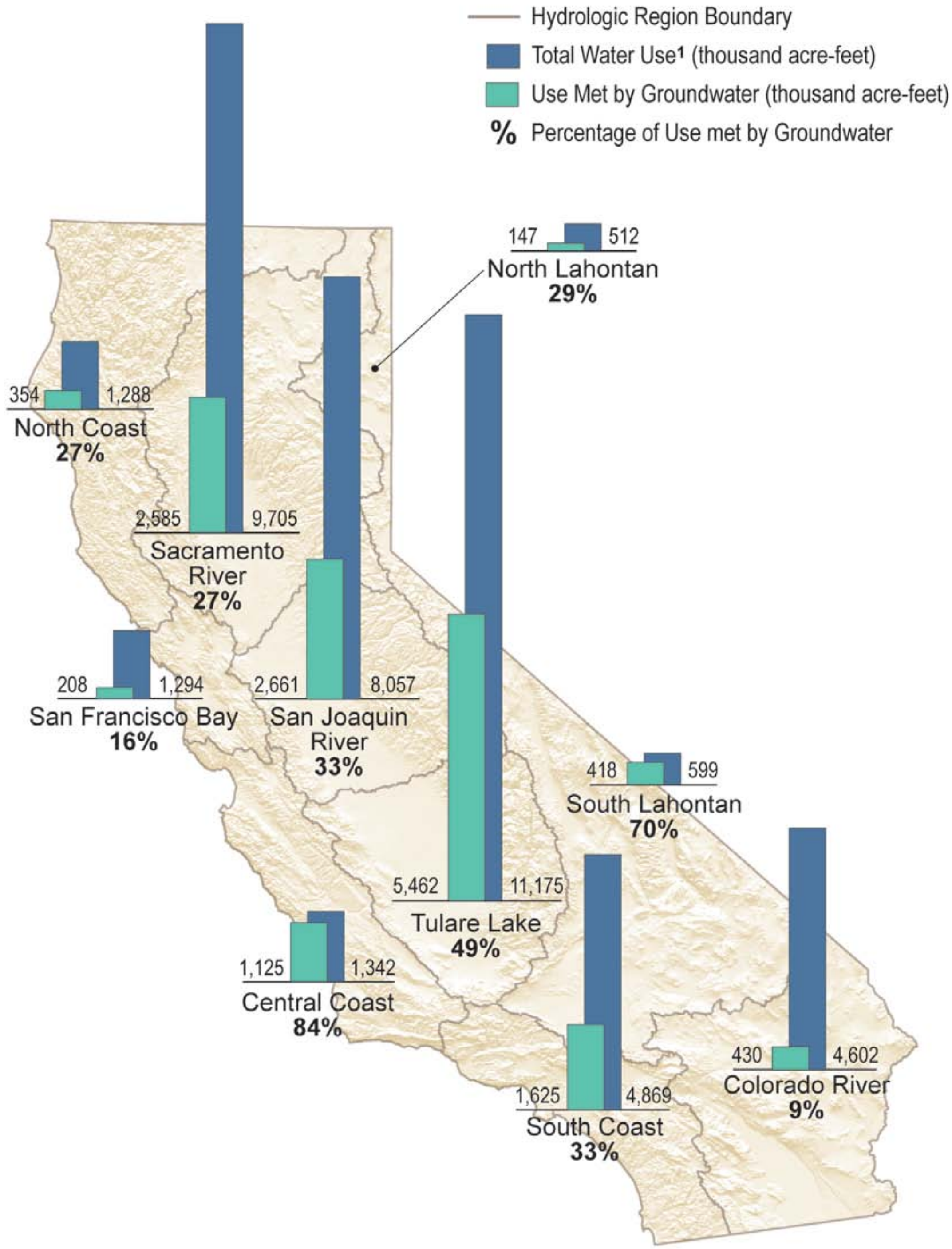
Groundwater has never been managed by the State; management has been considered a local responsibility by the State legislature (DWR, 2003). Management of groundwater is addressed locally through local ordinances, authority granted under the Water Code, or through adjudication. There are 515 delineated groundwater basins in California but only 22 basins are adjudicated, as shown in Figure 3-9. Adjudication of groundwater basins usually occurs when basin demand exceeds supply and the court must decide how much groundwater can be extracted from a basin.

Groundwater was an attractive water supply for early settlers of California due to its widespread availability. Artesian wells were initially used in the San Joaquin Valley, Los Angeles area, and San Francisco Bay Area to provide irrigation water in areas not located near major surface water. Individuals and families could simply dig a well or spring and develop a convenient source of water to support domestic use as well as other activities such as mining or agriculture. The development of groundwater supplies expanded during the early 1900s due to the availability of gasoline engines, electric power, and centrifugal pumps, which enabled people to pump larger quantities of water from wells.

During the 1920s, the development of deep-well turbine pumps and the availability of electricity in rural areas further increased the use of groundwater for irrigating agriculture. The use of pumps enabled farmers to irrigate large areas of land with low capital costs, resulting in a significant expansion of agriculture. Deep well pumps also allowed municipalities to provide dependable supplies in areas with minimal stream flow during the dry season. In the San Joaquin Valley, over 500 artesian wells and almost 600 electric- or gas-driven wells existed in 1906. By 1920, there were over 11,000 electric or gas-driven wells in the San Joaquin Valley. Groundwater overdrafts occurred rapidly in areas with low recharge rates.

Groundwater overdraft occurs when the water pumped exceeds the amount of water that naturally recharges the basin. In an overdrafted basin, groundwater levels decline and never fully recover, even during wet years. The consequences of overdraft include increased extraction costs, land subsidence, and water quality degradation. A comprehensive assessment of groundwater overdraft in California has not been completed since the publication of the 1980 edition of DWR's Bulletin 118 but, DWR estimates that statewide groundwater overdraft is somewhere between one and two million acre feet per year. A significant amount of this overdraft occurs in the Central Valley, particularly in the Tulare Lake Basin. Groundwater overdraft and management is discussed in the following sections using three case studies (Tulare Lake Overdraft, Santa Clara Valley Groundwater Management, and Central Basin Management).

Figure 3-8
Groundwater Use in California
Source: DWR, 2009



1 **1.** *Total Water Use is defined as the sum of water uses for agricultural, urban, and managed wetlands.* .

Figure 3-9
Groundwater Basins in California

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Case Study: Tulare Lake Overdraft

In the mid-1800s, most of the agricultural production in the San Joaquin Valley was related to grain and cattle production on overflow lands. Irrigated agriculture grew from less than 200,000 acres in 1880 to about 2,500,000 acres in 1960. Surface water was primarily used in this area from the 1860s until the 1927-1934 drought. Reliance on groundwater during that and subsequent dry years caused a substantial decline in groundwater elevations.

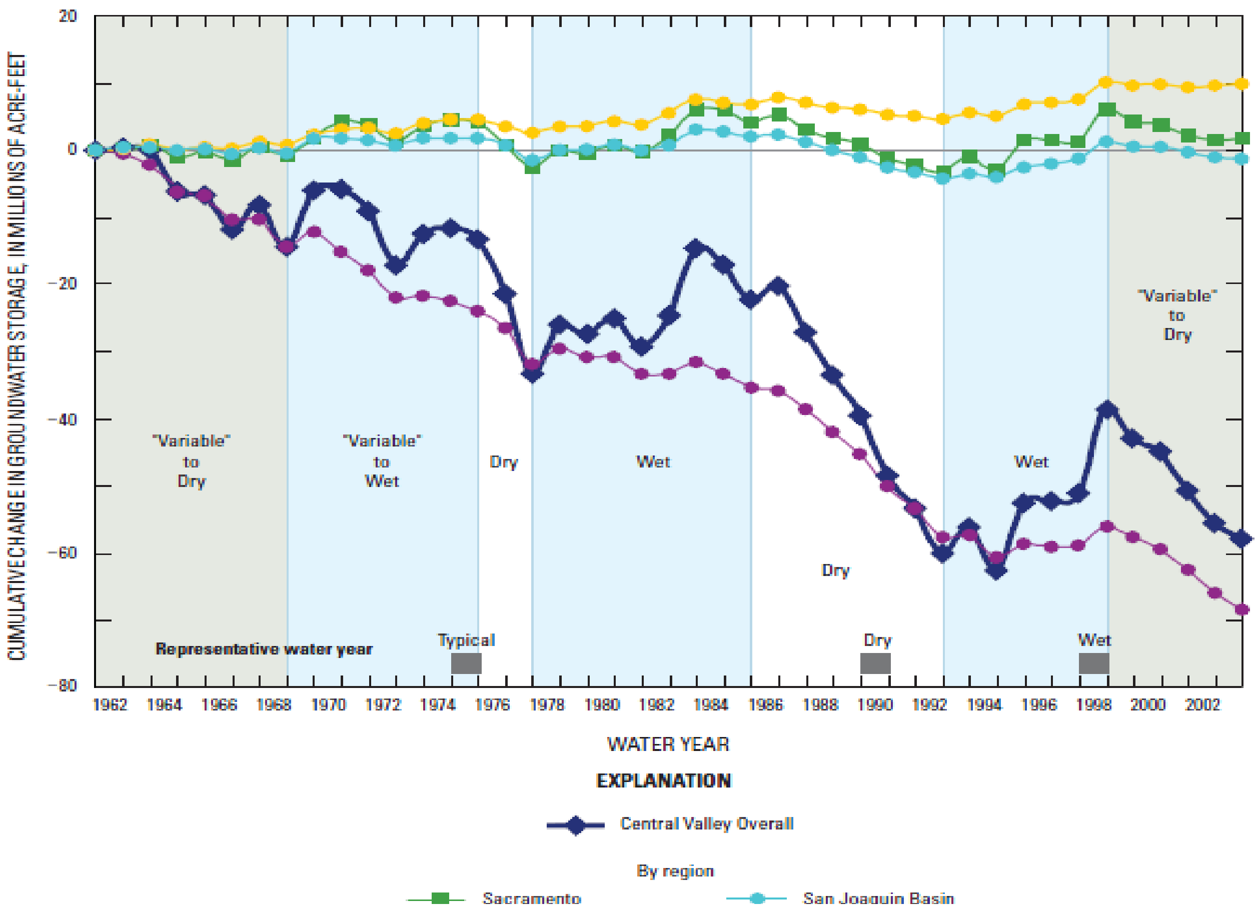
Studies were initiated in the late 1800s and early 1900s to identify methods to reduce groundwater overdrafts in the Fresno and Tulare basin areas of the San Joaquin Valley. In the late 1940s and early 1950s, the Friant-Kern facilities were completed to provide imported water to this area from the San Joaquin River. However, groundwater pumping continued to provide a major portion of water supplies in the area along the eastern San Joaquin Valley from the Mokelumne River to the Tehachapi Mountains. By 1960, there were about 40,000 wells in this area and groundwater elevations in much of the southern San Joaquin Valley had declined 50 to more than 200 feet between the spring of 1947 and the spring of 1957 (Reclamation, 1966). The decline in groundwater elevations was moderated in portions of this area following implementation of the Friant-Kern Canal. However, much of this area was not included in the CVP service area.

The 1956 Bulletin No. 3 (DWR, 1957) reported that about 8,250,000 acre-feet of groundwater was withdrawn in 1954 in the San Joaquin Valley, or 66 percent of the total groundwater used in the state. That report indicated that the ultimate water demand in the San Joaquin Valley of 16,310,000 acre-feet per year would require up to 8,330,000 acre-feet per year of imported water and development of 7,980,000 acre-feet per year from regional surface water and groundwater supplies. The revised 1957 Bulletin No. 3 (DWR, 1957) identified the San Joaquin Valley groundwater overdraft as 1,900,000 acre-feet per year following the importation of 1,365,000 acre-feet per year from the CVP. This report recommended that up to 7,800,000 acre-feet per year of imported water be provided to the San Joaquin Valley with expanded local surface water and groundwater storage of up to 7,700,000 acre-feet per year to meet the ultimate water demand of 15,500,000 acre-feet per year. The SWP was subsequently developed in the late 1960s to provide up to 1,182,700 acre-feet per year of imported water. However, the amount available on a long-term average annual basis is much less than the total contracted amount.

Several other studies were completed by Reclamation in the 1960s and 1970s that identified the need for additional projects to supply water to the Central Valley; however, these projects were not developed and groundwater overdraft has continued to increase, especially in the Tulare Lake basin. DWR estimated that the groundwater overdraft increased from 763,000 acre-feet per year in 1975 (Bulletin 118-80) to over 1,000,000 acre-feet per year in 2005 (Bulletin 160-2009). Recently, the USGS, working with DWR, compiled geological, water elevation, and well data throughout the valley and prepared a model to simulate the groundwater conditions in the Central Valley.

The USGS study indicates that the substantial reduction in groundwater storage in the Tulare Lake Region has occurred for several reasons. First, the Tulare Lake Region water demand has exceeded the water supplies in the basin for more than 120 years. During wet years, additional water has been available from runoff in the region and from the CVP and SWP exports to either directly increase groundwater storage in several groundwater banks or allow the groundwater to recharge by reducing pumping and relying upon the CVP and SWP supplies. During these years, groundwater storage has increased or stabilized, as shown in Figure 3-10. However, over the long-term water demands in this region are greater than the allocated water supplies from local runoff and groundwater recharge and CVP and SWP exports.

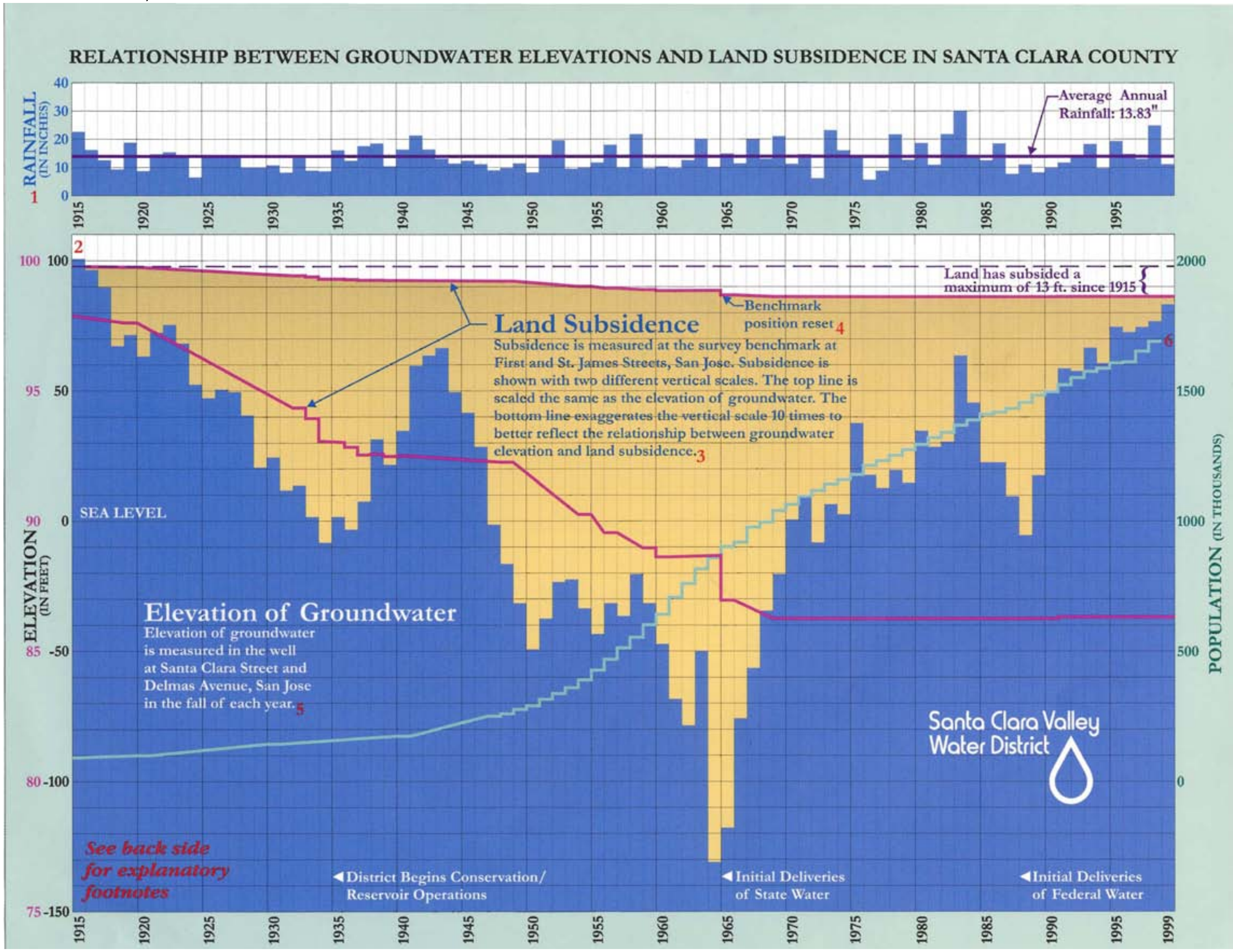
Figure 3-10
Groundwater Levels in the Central Valley, 1962-2003
Source: USGS, 2009



Case Study: Santa Clara Valley Groundwater Management

Groundwater supplies about half the water used in Santa Clara County. Groundwater levels in the Santa Clara basin have been declining since the 1900s and the area has experienced subsidence of over 13 feet and seawater intrusion at river mouths near the San Francisco Bay (DWR, 2003; SCVWD, 2001) as shown in Figure 3-11. Recharge in this basin occurs naturally along streambeds and artificially in instream and offstream managed basins. Storage capacity in the basin is 350,000 acre-feet. The Santa Clara Valley Water District has developed a groundwater management plan to address declining water levels, which includes groundwater monitoring, water conservation, and groundwater recharge. The SCVWD operates 18 major recharge systems covering an area of 390 acres and recharging 157,000 acre-feet annually. As seen in Figure 3-11, SCVWD management has been successful in preventing subsidence and recharging groundwater.

Figure 3-11
Groundwater Levels in the Santa Clara Basin
Source: SCVWD, 2010

1 

Case Study: Central Basin Management

The Central Basin serves water to over 4 million people in 43 cities in southeast Los Angeles County. The Central Basin along with the West Coast Basin comprise the Los Angeles Coastal Plain Basins. These basins are managed by the Water Replenishment District of Southern California. Together these basins cover approximately 420 square miles and store up to 20 million acre-feet. In the 1960s, groundwater pumping exceeded 290,000 acre-feet per year in the Central Basin and 94,000 acre-feet per year in the West Coast Basin. This was double the safe yield of the basin (173,400 acre-feet per year for Los Angeles Coastal Plain Basins) as determined by DWR. DWR set an allowable pumping limit of 217,367 acre-feet per year in the Central Basin and 64,468 acre-feet per year in the West Coast Basin.

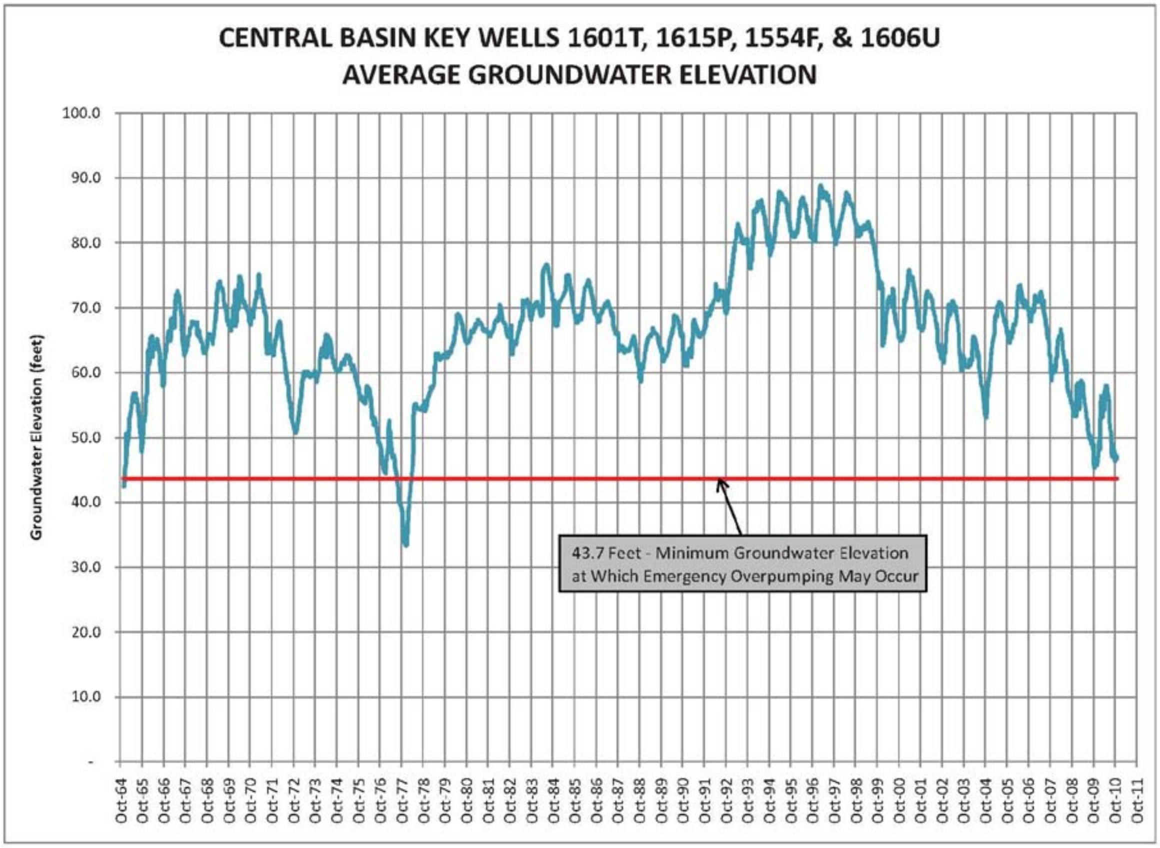
The overpumping in the basins resulted in lost groundwater from storage as well as seawater intrusion in the coastal edges of the aquifers. The DWR allowed pumping rate is higher than the natural recharge available to the basins so SWP and recycled water are used to artificially recharge the basins. If this recharge water is not available the groundwater basins are in annual overdraft. The SWP water supplied for recharge is “surplus Tier 1” water from Metropolitan Water District, which is only available when excess supply exists. This surplus water is typically available in seven out of ten years; however, this may change in the future with increasing water demands and decreasing SWP supplies.

During the last ten years, there have been two years where storage was gained and eight years where storage was lost. The average loss from storage has been 17,100 acre-feet per year or a total of 171,000 acre-feet. This loss of storage has occurred due to lack of replenishment water and dry water years. This has resulted in historic lows for groundwater in the southern portion of the Central Basin and average elevations in the Central Basin being near the 32 year lows as shown in Figure 3-12.

Metropolitan also has a conjunctive use agreement with city of Long Beach to store up to 13,000 acre-feet and another agreement with Lakewood to store an additional 3,600 acre-feet. The 13,000 acre-foot account was filled in 2003 and 50 percent of the 3,600 acre-foot account was filled in 2006 and 2007. Metropolitan has called more than half of this water from storage. This has exacerbated the issue of declining groundwater levels in the southern portion of the aquifer.

In November of 2010, the Water Replenishment District, who manages the basin, declared a water emergency due to the declining groundwater levels. This declaration limits groundwater extraction from the basin to protect the basin from further overdraft.

Figure 3-12
Average Groundwater Elevation in Key Central Basin Wells
Source: WRD, 2010



Water Recycling

Water recycling has been used in California since the early 1900s to augment water supplies in areas where water is scarce. Water recycling reuses an existing water source in the region for landscape irrigation, agricultural irrigation, commercial use, groundwater recharge or other miscellaneous uses. The amount of recycled water available is limited by water use and wastewater production. Therefore, if water use declines and less wastewater is produced then less recycled water would be available. Since 1970 there has been a threefold increase in the amount of water recycling. In 2002, DWR estimated that between 450,000 and 580,000 acre-feet of recycled water was used in California. Recycled water is used primarily to irrigate landscapes (21 percent), irrigate agriculture (46 percent), and recharge groundwater (14 percent). This is expected to increase to between 1.85 and 2.25 million acre-feet by 2030 (DWR, 2009).

Recycled water projects are typically developed as part of new developments (i.e., dual plumbing, where separate piping systems for both potable and recycled water are implemented) or retrofit of existing potable users. Dual plumbing is implemented in many parts of the state for new development to help meet water needs and makes construction of recycled water systems cost effective. Implementation of recycled water projects in established areas is costly and challenging due to existing infrastructure and disruption of the public. Due to the costs associated with retrofit projects, a majority of these projects are developed to serve large users (usually industrial or groundwater recharge basins) with smaller irrigation projects connected along the planned pipeline route. Maximizing reuse will require significant investment and identification of large users. The following subsections will provide three case studies (Central Valley, San Francisco Bay Area, and Sothern California) illustrating how water is reused in California as well as issues facing the use of recycled water projects.

Case Study: Central Valley

The City of Bakersfield has reused wastewater since 1912 to irrigate crops (Asano, 1998). The city continues this practice today by using recycled water for agricultural and urban irrigation as well as groundwater recharge. The city is one of the largest producers of recycled water in the state. By 2025 recycled water use is projected to be 20,000 acre-feet per year. Recycled water use in Fresno-Clovis area consists of secondary treatment of 80 million gallons per day (mgd) of wastewater and disposal in evaporation ponds. Water in the evaporation ponds results in incidental recharge of the groundwater basin. Farmers in the region also divert approximately 7,400 acre-feet per year of water from the ponds for irrigation. Total recycled water produced by this effort is approximately 65,300 acre-feet per year (Fresno, 2008). In addition, the North Fresno Recycled Water Project is projected to supply between 750 and 1,000 acre-feet per year for gold course irrigation. In most of the communities, water is recycled for use by irrigators. Agricultural tailwater return systems are also used to recover and reuse water. These return systems collect runoff and transport it to the main irrigation system. Recycled water also is used to supply water to the Kern National Wildlife Refuge. Using recycled water to replace potable water uses extends existing supplies but cannot fully address water supply needs in the Central Valley.

Case Study: San Francisco Bay Area

Water recycling was first used in the San Francisco Bay Area in 1932 when wastewater was used to irrigate landscape in Golden Gate Park. However, widespread water recycling did not occur until the late 1980s. The East Bay Municipal Utility District currently serves the most recycled water. In 2005, approximately 30,000 acre-feet per year of recycled water was produced for urban and agricultural irrigation, industrial/commercial needs, and environmental restoration. Recycled water produced could expand up to 125,000 acre-feet per year in 2010. Funding and institutional issues limit the amount of water recycling in the Bay Area (BAWAC, 2009c). Agencies in the San Francisco Bay area have been working together to gain state and federal support for water recycling projects since the late 1990s. The Bay Area Regional Recycling Program was developed as part of this effort. To date, Bay Area agencies have received over $21 million in funding for water recycling projects as part of the Bureau of Reclamation’s Water Recycling and Reuse Program, Title XVI. However, this funding is only a portion of the $104 million needed for project development, as shown in Table 3-2. Identifying funding sources is important to expanding water recycling in the San Francisco Bay Area.

Table 3-2
List of Title XVI Projects in the San Francisco Bay Area

Project	Funded under Title XVI	Total Project Cost
Pacifica Recycled Water Project - Pipeline, North Coast County Water District	$2,203,750	$8,815,000
San Jose Water Reclamation and Reuse Project Phase 1C, South Bay Water Recycling	$6,460,000	$25,830,000
South Bay Advanced Recycled Water Treatment Facility, Santa Clara Valley Water District	$8,250,000	$52,655,000
South Santa Clara County Recycled Water Master Plan Implementation, Santa Clara Valley Water District	$4,350,000	$17,116,000
Total	$21,263,750	$104,416,000

Source: Reclamation, 2010a

Case Study: Southern California

Recycled water has been used since 1906 in Oxnard and 1932 in the city of Pomona for irrigation (Reclamation, 2006). Large-scale water reuse in the region began in the early 1960s with artificial recharge of groundwater at Whittier Narrows and urban irrigation and industrial use within Irvine Ranch Water District's service area. Currently, over 400,000 acre-feet per year of recycled water has been developed in Southern California (Reclamation, 2009) for groundwater recharge/seawater intrusion, industrial uses, and irrigation (urban and agricultural), as shown in Figure 3-13.

Currently, there are over $550 million in planned projects in Southern California that have been identified and funded under Reclamation's Title XVI (Reclamation, 2010a). In addition to the Title XVI projects, there are several large-scale water recycling projects under development by local agencies, listed in Table 3-3. A majority of these projects are groundwater recharge projects, but the city of San Diego is investigating an indirect potable reservoir augmentation project.

Figure 3-13
Existing Recycled Water Use Types in Southern California Region
Source: DWR, 2009

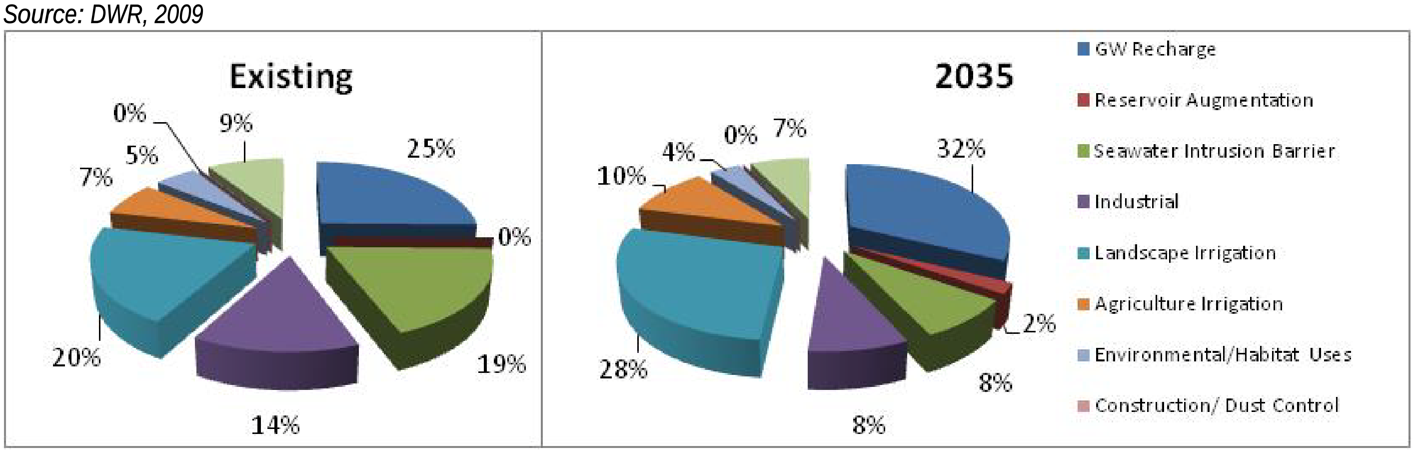


Table 3-3
List of Potential Recycled Water Projects in Southern California

Project Name	Description
Groundwater Reliability Improvement Program	Increase reuse at San Jose Creek WRP to include 46,000 acre-feet per year for groundwater recharge in the Central and Main San Gabriel groundwater basins by 2020
East Valley Recharge Project	Produce 33,000 acre-feet per year of advanced treated water at Donald C. Tillman WRP for recharge in San Fernando Basin
Leo J. Vander Lans Plant Expansion	Expansion of advanced treatment to supply additional 3,000 to 5,000 acre-feet per year of water to Alamitos Seawater Intrusion Barrier
City of Escondido Advanced Tertiary Treatment Project	Reuse for groundwater recharge or instream use of 6 to 8 mgd
City of San Diego Indirect Potable Reuse Project	Advanced treatment of North City WRP flows for indirect potable reuse. Demonstration project is 1 mgd
CVWD Non-potable Water Supply System	Blend of over 50,000 acre-feet per year of recycled water and canal water for irrigation at 50 golf courses

Source: Reclamation, 2009

Desalination

Desalination includes treatment of seawater and brackish water sources for water supply needs. In California, desalination began in the 1960s but there has been a rapid increase in the number of facilities developed in the past ten years. This rapid expansion is due to advancements in membrane treatment, increases in potable water costs, and reduction in desalination costs. Today, 20 groundwater desalination plants and 6 seawater desalination plants are in operation producing over 84,000 acre-feet of water annually. Groundwater desalting has advanced more than seawater desalination because salinity levels are magnitudes lower in groundwater (i.e., TDS of seawater is typically 30,000-40,000 milligrams per liter [mg/l] while brackish groundwater has a TDS of 1,000 to 10,000 mg/L).

Seawater Desalination

Currently, the only existing seawater desalination plant in areas that export water from the Delta watershed is owned by the city of Santa Barbara. This plant was constructed in 1991 to 1992 by the City of Santa Barbara, Goleta Water District, and Montecito Water District as an emergency water supply in response to the severe drought lasting from 1986 to 1991. The latter two agencies are no longer participants in the desalination plant, which is currently decommissioned due to ample quantities of less expensive supplies. The desalination facility can, however, be brought into operation within 6 to 12 months if needed during drought or water shortage conditions. Just over half of the prefiltration capacity and reverse osmosis treatment modules were sold, leaving sufficient capacity to meet the City's anticipated need for approximately 3,000 acre-feet per year of production in future droughts. There are several seawater desalination plants proposed as shown on Table 3-4. Seawater desalination is planned for communities along the California coast from San Francisco to San Diego. To date, over 270,000 acre-feet of water production has been proposed.

Table 3-4
Proposed Seawater Desalinations Plants in California

Project	Agency	Project Size (acre-feet per year)	Project Status
Bay Area Regional Desalination Project	CCWD, EBMUD, SCVWD, and SFPUC	22,400-79520	Pilot study concluded, member agencies contract under negotiation
Marin County Seawater Desalination Project	Marin Municipal Water District	5,600-16,800	Pilot Study and EIR complete; on-hold
Long Beach Seawater Desalination Project	Long Beach	10,000	Pilot study1
Los Angeles Seawater Desalination Project	Los Angeles Department of Water and Power	28,000	On hold
South Orange Coastal Ocean Desalination Project	Municipal Water District of Orange County	16,000-28,000	Pilot study1
Carlsbad Seawater Desalination Project	San Diego County Water Authority	56,000	Construction
West Basin Seawater Desalination Project	West Basin Municipal Water District	20,000	Pilot study1
Huntington Beach Seawater Desalination Project	Municipal Water District of Orange County	56,000	Certified Final EIR; CDP/permits still pending
Camp Pendleton Seawater Desalination Project	San Diego County Water Authority	56,000 to 168,000	Planning; Advisory RFP Issued

Project	Agency	Project Size (acre-feet per year)	Project Status
Rosarito Beach Seawater Desalination Feasibility Study2	San Diego County Water Authority	28,000 to 56,000	Feasibility study
Total		270,000 to 422,000	

Notes:
[1] Full scale feasibility and design studies are underway at these locations.
[2] Includes water for service outside of southern California region.

Groundwater Desalination

Groundwater is an important source of water supply in California; however, some of the groundwater basins are brackish or have other water quality issues that require additional treatment prior to use. Groundwater quality is degraded through increased salinity and other constituents introduced by agricultural and municipal activities, past industrial/commercial activities, seawater intrusion, or from naturally existing conditions. Treatment of brackish groundwater is currently occurring in the San Francisco Bay and southern California areas.

Treatment of brackish groundwater is allowing previously unused groundwater to be used as a potable water source in the San Francisco Bay area and southern California. In 2003, the first groundwater desalination plant went into production in Northern California. The 5-mgd Alameda County Water District Newark Desalination Facility removes salts and other constituents from the Niles Cone Groundwater Basin groundwater (part of the Santa Clara basin) for supply as potable water. This plant uses reverse osmosis process and discharges brine to a flood control channel. In 2009 the Zone 7 Water Agency began operation of the Mocho Groundwater Demineralization Plant. This plant produces 6.1 mgd of potable water for blending with other water supply sources. The Mocho Groundwater Demineralization Plant uses reverse osmosis to remove salinity and hardness from the Livermore-Amador Valley's groundwater basin and discharges brine to the Dublin San Ramon Sanitation District brine sewer line.

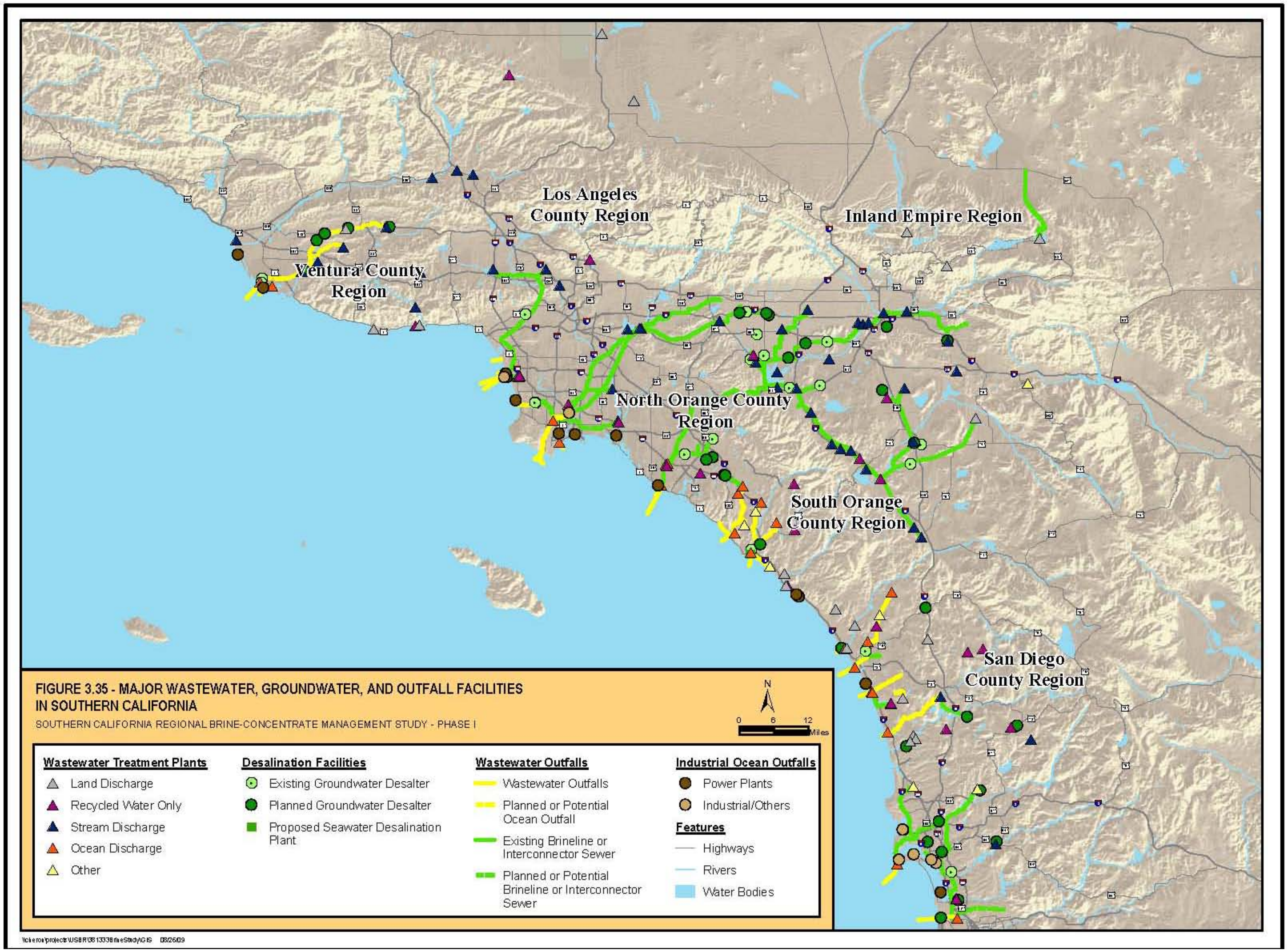
Brackish groundwater in Southern California exists primarily in San Diego, areas of the Inland Empire, and coastal areas of Los Angeles and Orange Counties. Development of this water may be limited because of availability of brine disposal systems, treatment costs, and declining groundwater elevations. For example, the Santa Ana Regional Interceptor is experiencing capacity limitations that may impede future brackish desalination. 28 groundwater desalter and ion exchange facilities are either planned or in operation to reclaim brackish (total dissolved solids > 1,000 mg/L) or poor quality groundwater, as shown on Figure 3-14. These facilities as well as several industrial facilities and other groundwater remediation sites utilize brine pipelines or sewers for waste disposal. Table 3-5 summarizes the location and production capacities of these desalting facilities. Groundwater desalter projects are planned in the Inland Empire and Ventura County areas. These projects would desalt degraded groundwater for supply to irrigation uses. For example, the Los Posas Basin or Moorpark Desalter is a planned 5-mgd desalter to reclaim brackish groundwater for agricultural uses in Ventura County. These groundwater supplies are limited by water available for conjunctive use (i.e., groundwater recharge) and overdraft.

Table 3-5
Amount of Existing and Planned Groundwater Desalting in Southern California

	Planning Year 2010			Planning Year 2035		
Local Area	**Capacity (mgd)**	**Maximum Daily Flow (mgd)**	**Average Daily Flow (mgd)**	**Capacity (mgd)**	**Maximum Daily Flow (mgd)**	**Average Daily Flow (mgd)**
Ventura County	11.50	11.50	11.50	39.63	39.63	39.63
Los Angeles County	36.14	36.14	31.14	38.64	38.64	38.64
Inland Empire	30.96	30.96	30.20	78.01	78.01	77.41
Orange County*	20.43	19.43	19.43	86.64	85.64	82.40
San Diego County	21.20	21.20	19.95	49.85	49.85	46.05
Total	120.23	119.23	112.22	292.77	291.77	284.13

Source: Reclamation, 2009
*Data includes South Orange County Coastal Ocean Desalination Project in 2035.

Figure 3-14
Groundwater Desalters in Southern California
Source: DWR, 2009



Section 4 Projected Future Risks due to Climate Change and Sea Level Rise

There are many risks to future Delta water supplies. One of the most critical risks to water resources is related to projected climate change and sea level rise.

Effects of Climate Change and Sea Level Rise

A growing body of evidence indicates that Earth's atmosphere is warming. Records show that surface temperatures have risen about 0.7°C (33.3°F) since the early twentieth century and that 0.5°C (32.9°F) of this increase has occurred since 1978 (National Academies of Sciences [NAS] 2006 summary, U.S. Global Change Research Program [USGRP] 2001). Observed changes in oceans, snow and ice cover, and ecosystems are consistent with this warming trend (NAS 2006; Intergovernmental Panel on Climate Change [IPCC] 2001, 2007). The temperature of Earth's atmosphere is directly related to the concentration of atmospheric greenhouse gases. Growing scientific consensus suggests that climate change will be inevitable as the result of increased concentrations of greenhouse gases and related temperature increases (IPCC, 2001, 2007; Kiparsky and Gleick, 2003).

Earth's climate has exhibited variability and has changed over time. The extremes of the 100,000-year ice-age cycles and "mega-droughts" have been well documented. The period of the last 10,000 years has been generally warm and stable, and the last millennium, over which current societies have developed, has been one of the most stable climatological periods observed (California Environmental Protection Agency [CalEPA], 2006). Observations in the twentieth century indicate rapid climate change (IPCC 2001, 2007; NAS, 2006). The National Academy of Sciences (2006) recently supported the conclusion that it is likely that the past few decades exhibited higher global mean surface temperatures than during any comparable period of the preceding four centuries. Additionally, 11 years between 1995 and 2006 rank among the 12 warmest years in the instrumentation record (1850–2006) for global surface temperature (IPCC, 2007).

Climate Variability and Climate Change

In common terms, "climate" is the "average weather" conditions over some extended period. The IPCC (2001) provides a more rigorous definition of climate as the "statistical description in terms of the mean and variability of relevant parameters over a period of time ranging from months to thousands or millions of years." Parameters measured are most often surface variables such as temperature, precipitation, and wind. Data are typically averaged in 30-year periods as defined by the World Meteorological Organization.

"Climate change" is the shift in the average weather, or trend, that a region experiences. This change may result from natural processes, or from anthropogenic factors that affect the composition of the atmosphere. Consequently, climate change cannot be represented by single annual events nor individual anomalies. For example, a single large flood event or particularly hot summer is not an indication of climate change, whereas a series of floods or warm years that statistically change the average precipitation or temperature over time may indicate climate change.

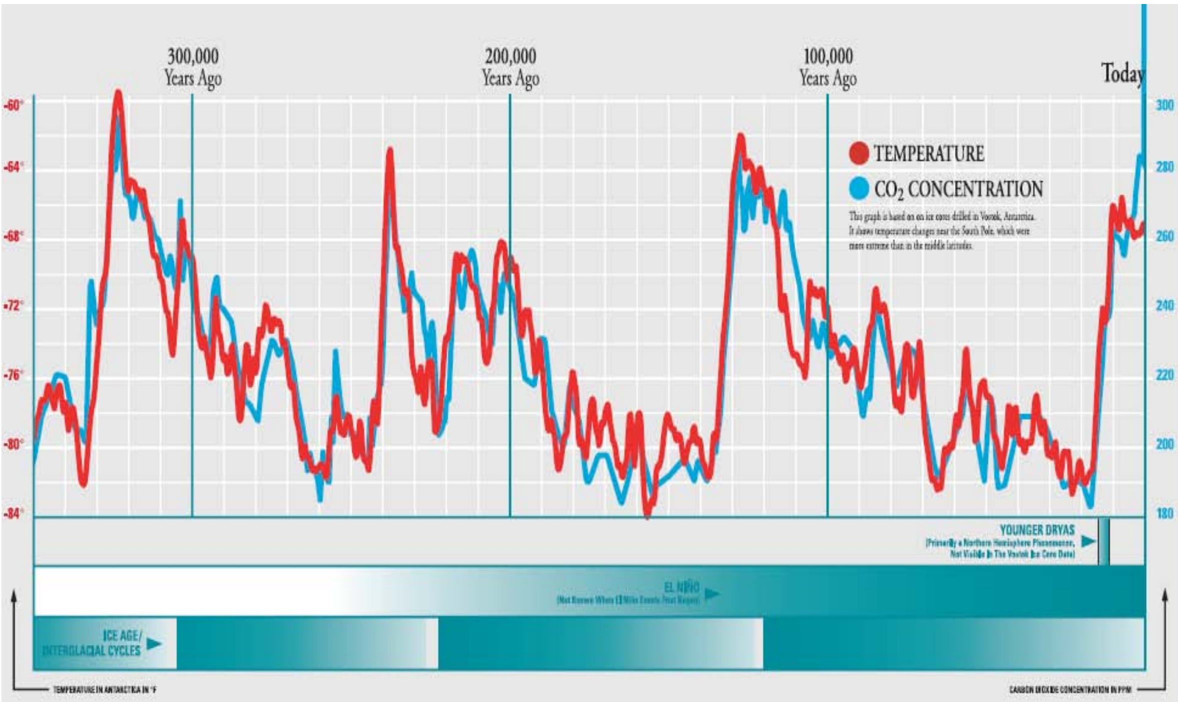
"Climate variability" refers to the deviation from the average climate. For example, an individual year that is drier or hotter than average would indicate variability, but may not indicate a shift in the trend as would be defined as climate change.

Mechanics of Climate Change

The temperature on Earth is regulated by a system commonly described as exhibiting the "greenhouse effect." The greenhouse effect is a natural phenomenon in which atmospheric gases—primarily water vapor, carbon dioxide, methane, nitrous oxide, and ozone—allow solar radiation to pass through the atmosphere and warm Earth's surface. As Earth's surface warms, infrared radiation is emitted back to the atmosphere. Greenhouse gases (GHGs) in the atmosphere absorb some of this radiation and re-emit it back to Earth, causing the surface to gain more heat (NAS, 2006). Changes in atmospheric gases can result in changes in Earth's temperature, thereby influencing climate.

Changes in the atmospheric abundance of GHGs, as well as modifications to the land surface, alter the energy balance of the climate system. GHGs are contributed to the atmosphere by both natural and human-created sources. Evidence suggests that the rates of contribution of GHGs to the atmosphere were in balance with mechanisms for their removal before the early 1800s (North et al., 1995). Data on atmospheric carbon dioxide concentration indicate a cyclical pattern. The concentration of carbon dioxide in the atmosphere has risen about 30 percent since the late 1800s and is now higher than it has been in at least the last 400,000 years, as shown in Figure 4-1 (USGRP, 2001). Although the causes of increasing concentrations of carbon dioxide are still subject to some debate, the climate effects and implications for water resource planning remain. Rising concentrations of carbon dioxide and other GHGs are intensifying Earth's natural greenhouse effect. Global projections of population growth and assumptions about energy use indicate that the carbon dioxide concentration will continue to rise, likely reaching between two and three times its late-nineteenth-century level by 2100 (USGRP, 2001).

Figure 4-1
Trend of Carbon Dioxide Accumulation in Earth's Atmosphere
Source: NAS, 2006



Observed Trends and Future Projections of California's Climate

Climate changes have been observed related to changes in temperature, precipitation, and sea level rise, as summarized below.

Temperature

Observed climate and hydrologic records indicate that more substantial warming has occurred since the 1970s and that this is likely a response to the increases in GHG increases during this time, as shown in Figure 4-2. Historical simulations with global climate models exhibit a similar response, providing a basis for our understanding of causal mechanisms. The current suite of global climate models, when simulated under future GHG emission scenarios and current atmospheric GHGs, exhibit warming—globally and regionally over California—as shown in Figure 4-3. In the early part of the twenty-first century, the amount of warming produced by the higher-emission scenario is not very different from the lower-emission scenario, but becomes increasingly larger through the middle and especially the latter part of the century. Six global climate models selected by the California Climate Action Team (CAT) for its 2009 scenarios project indicate a mid-century temperature increase of about 1°C to 3°C (1.8°F to 5.4°F) and an end-of-century increase from about 2°C to 5°C (3.6°F to 9°F). The upper part of this range is a considerably greater warming rate than the historical rates estimated from observed temperature records in California (Bonfils et al., 2008).

Figure 4-2
Historical Observed California Mean Annual Temperature Departure
Source: Western Regional Climate Center, 2009

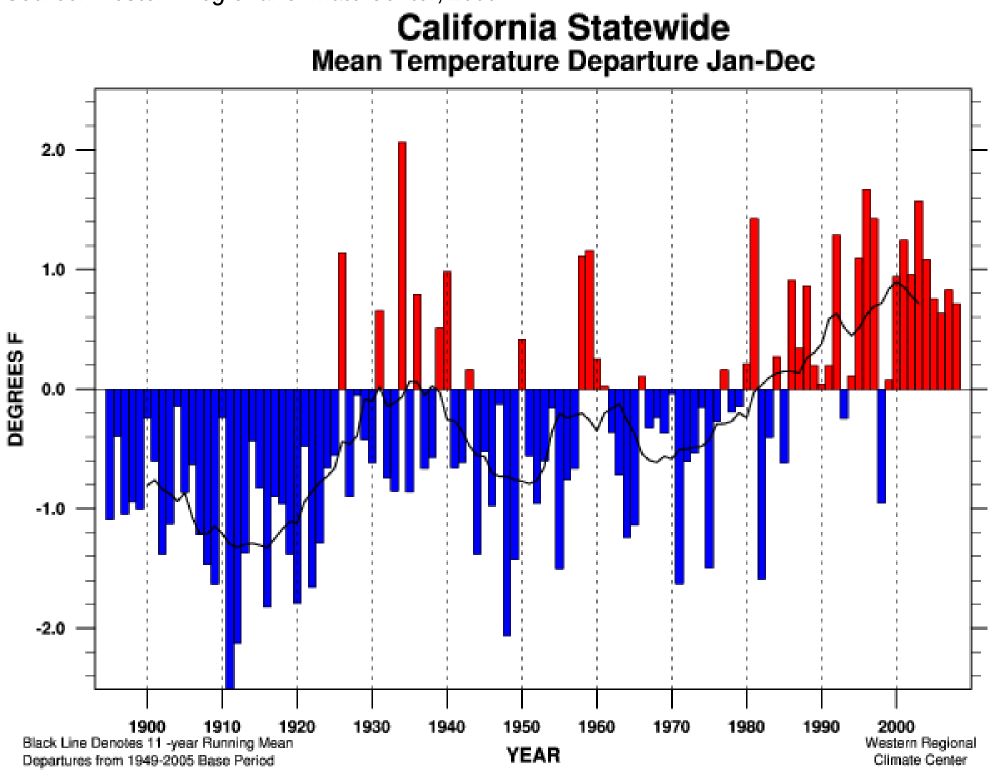
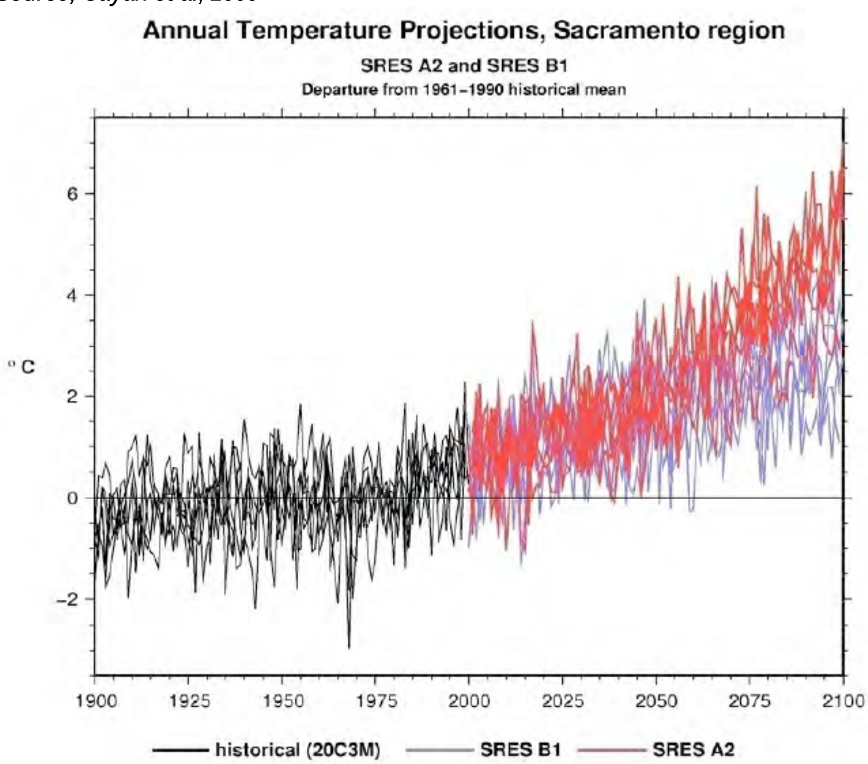


Figure 4-3
Simulated Historical and Future Annual Temperature Projections for the Sacramento Region
Source; Cayan et al, 2009



Precipitation

Precipitation in most of California is dominated by extreme variability over seasonal, annual, and decade time scales, as shown in Figure 2-2. The global climate model simulations of historical climate capture the historical *range* of variability reasonably well (Cayan et al., 2009). However, historical *trends* are not well captured in these models. Projections of future precipitation are much more uncertain than those for temperature. Although it is difficult to discern strong trends from the full range of climate projections, the six global climate models that were selected for the California study demonstrate a drying trend in the twenty-first century. The precipitation projection uncertainty is largest in the northern part of the state, and a stronger tendency toward drying is indicated in the southern part of the state. However, even for hydrologic model simulations with mean precipitation virtually unchanged, there were large impacts on snowpack accumulation, runoff, and soil moisture.

Sea Level Rise

Global and regional sea levels have been increasing steadily over the past century and are expected to continue to increase throughout this century. Recent work by Stefan Ramsdorf (an IPCC coauthor) suggests that the sea level rise may be substantially greater than the IPCC projections. In the CAT 2009 most recent assessment, sea level rise projections were derived based on empirical relationships between global mean surface air temperature and global mean sea level as described by Ramsdorf (2007). This method better reproduces historical sea levels but generally produces larger estimates of sea level rise than those indicated by the IPCC (2007) and other recent estimates. However, the method described by Ramsdorf is consistent with the methods used in the recent summary recommendation on sea level rise from the CALFED Independent Science Board (Healy, 2007). When evaluating all global air temperature projections and factoring for the range of uncertainty, up to 140 cm (55 inches) of sea level rise is projected for the end of the century, as shown in Figure 4-4. From the scenarios selected for CAT report, sea level rise by 2050 is projected to be 30 cm (12 inches) to 45 cm (18 inches) and up to 55 inches by 2100.

Recent State and Federal Approaches for Incorporating Climate Change in California

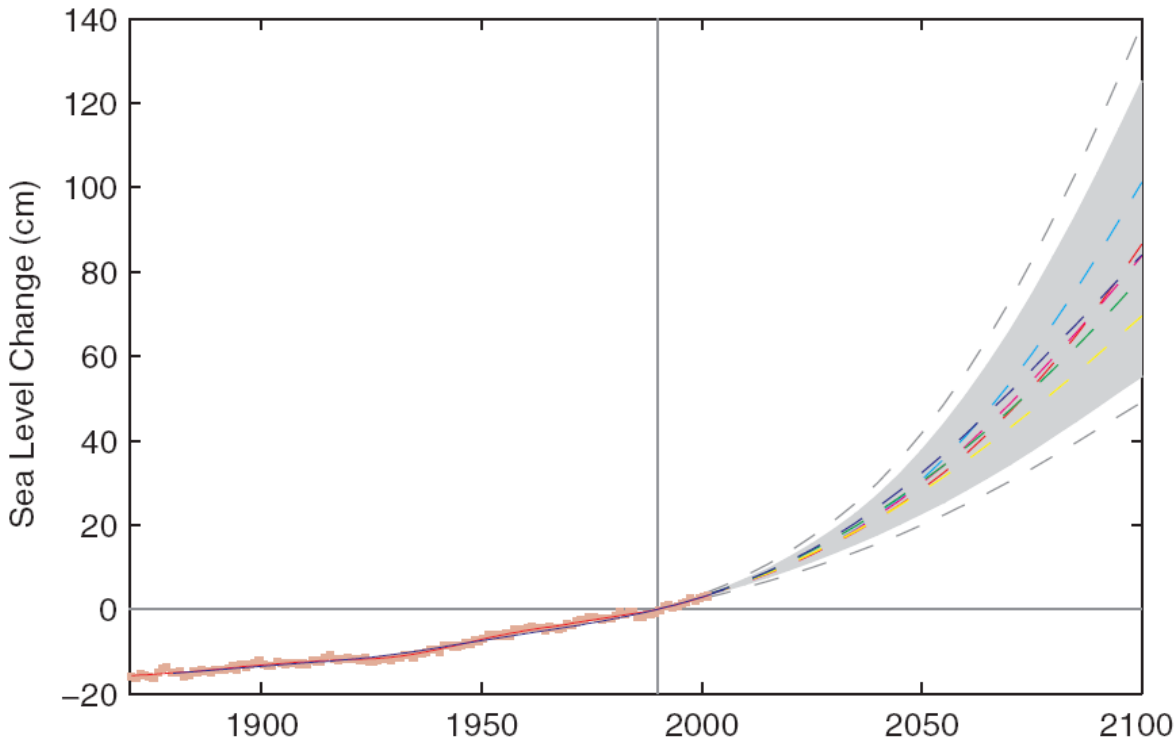
General consensus has been reached on some aspects of regional climate change projections (direction of temperature and sea level rise), but other aspects are not well understood (precipitation trends in California).

Future climate change projections are made primarily on the basis of global climate model simulations under a range of future emission scenarios. Currently, approximately 20 major global climate models are supported by national institutions worldwide. Global climate models have improved significantly in recent years, but the models continue to have substantial uncertainty, especially for regional conditions.

The coarse scale of global models requires results to be “downscaled” (applied to a region or watershed). Whether through dynamic or statistical methods, downscaling adds another source of uncertainty to projections. In addition, the range of projections, especially beyond 2030, is governed by assumed future global emissions. The IPCC (2001, 2007) has developed a range of possible future GHG emission scenarios based on assumptions of fossil fuel use, regional political and social conditions, technologies, population, and governance and associated emissions that could occur in the future.

Approaches to predicting climate change have been developed by the California Climate Action Team, the San Francisco Bay Conservation and Development Commission, the U.S. Department of the Interior, USEPA, and USACE. These approaches will be considered in more detail during the preparation of the Delta Plan.

Figure 4-4
Historical Global Mean Sea Level and Future Projections based on Global Mean Temperature Projections
Source: Ramsdorf 2007



Section 5 References

Asano, Takashi. 1998. Water Reclamation and Reuse.

Bay Area Water Agencies Coalition (BAWAC). 2006a. San Francisco Bay Area Regional Integrated Management Plan.

Bonfils, Céline, and Coauthors, 2008. Detection and Attribution of Temperature Changes in the Mountainous Western United States. Journal of Climate, 21, 6404–6424.

California Emergency Management Agency (CalEMA). 2010. 2010 California State Hazard Mitigation Plan.

California Environmental Protection Agency (CalEPA). 2006. Climate Action Team Report to Governor Schwarzenegger and the Legislature. March.

Cayan et al. 2009. Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment.

City of Fresno. 2008. Urban Water Management Plan.

City of Los Angeles. 2000. Integrated Plan for the Wastewater Program: Tools Technical Memorandum.

Department of Finance (DOF). 2009. California County Population Estimates and Components of Change by Year, July 1, 2000-2009.

California Department of Water Resources (DWR). 1931. Variation and control of salinity in 4 Sacramento-San Joaquin Delta and upper San Francisco Bay. DWR Bulletin No. 27.

DWR. 1957. Interim Report to the California State Legislature on the Salinity Control Barrier Investigation. DWR Bulletin No. 60

DWR. 1957. The California Water Plan. DWR Bulletin No. 3

DWR. 1968. Municipal and Industrial Water Use. DWR Bulletin No. 166-1.

DWR. 1974. Bulletin No. 118-3: Evaluation of Ground Water Resources: Sacramento County.

DWR. 1975. Urban Water Use in California. DWR Bulletin No. 166-2.

DWR. 1983. Urban Water Use in California. DWR Bulletin No. 166-3.

DWR. 1994. Urban Water Use in California. DWR Bulletin No. 166-4.

DWR. 2003. California's Groundwater Update 2003. DWR Bulletin No. 118

DWR. 2005. California Water Plan 2005 Update. DWR Bulletin 160-05.

DWR. 2009. California Water Plan 2009 Update. DWR Bulletin 160-09.

DWR. 2010a. Public Review Draft California Drought Contingency Plan.

DWR. 2010b. DWR Public Water Systems Survey.

DWR, State Water Resources Control Board, Calfed Bay-Delta Authority, California Energy Commission, California Department of Public Health, California Public Utilities Commission, and California Air Resources Board. 2010. 20x2020 Water Conservation Plan. February.

DWR and CDFA, 2008. Current Water Use Efficiency Policy and Programs and Estimate of Urban and Agricultural Water Use. Prepared for the Delta Vision Blue Ribbon Task Force.

DWR Division of Safety of Dams. 2010c. Website: http://www.water.ca.gov/damsafety/damlisting/index.cfm. Accessed 2010.

Governor's Office of Planning and Research, in cooperation with DWR. 1978. California Water Atlas.

Hudley, Norris. 2001. The Great Thirst – Californians and Water: A History Revised edition.

Intergovernmental Panel on Climate Change (IPCC). 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press.

Jackson, W. Turrentine, and Paterson, Alan M. 1977. The Sacramento-San Joaquin Delta: The Evolution and Implementation of Water Policy: An Historical Perspective

Kiparsky, M and Gleick, PH. 2003. Climate Change and California Water Resources: A Survey and Summary of the Literature.

Los Angeles Department of Water and Power (LADWP). 2010. History of LADWP – William Mulholland website. http://www.ladwp.com/ladwp/cms/ladwp001562.jsp

Legislative Analyst's Office (LAO). 2008. California Water: An LAO Primer.

Mulholland, Catherine. 2000. William Mulholland and the Rise of Los Angeles.

North, G. R., K.-Y. Kim, S. P. Shen, and J. W. Hardin. 1995. Detection of forced climate signals. Part I: filter theory, Journal of Climate, 6, 401-408.

Olmstead, Alan L and Rhode, Paul W. 2004. *The Evolution of California Agriculture, 1850-2000,* California Agriculture: Dimensions and Issues.

Office of Environmental Health Hazard Assessment (OEHHA). 2009. Indicators of Climate Change in California.

National Academy of Sciences (NAS). 2006. Surface Temperature Reconstructions for the Last 2,000 Years. National Academies Press.

National Water Research Institute (NWRI). 2007. An NWRI White Paper: Water 2010, A Near Sighted Program of Water Resource Management Improvements for the Western United States.

Ramsdorf, S. 2007. A semi-empirical approach to projecting future sea level. Science, vol 315. January.

United States Department of the Interior Bureau of Reclamation (Reclamation). 1966. Central Valley Project East Side Division, Initial Phase; A Report on the Feasibility of Water Supply Development.

Reclamation. 2006. Southern California Water Recycling Projects Initiative.

Reclamation. 2009. Southern California Regional Brine Management Study.

Reclamation. 2010a. Reclamation's Title XVI Website. http://recovery.doi.gov/press/bureaus/bureau-of-reclamation/title-xvi-projects/Project

Reclamation. 2010b. Colorado River Basin Water Supply and Demand Study: Public Outreach Meeting.

Santa Ana Watershed Project Authority (SAWPA). 2009. Santa Ana Integrated Watershed Plan.

United States Geological Survey (USGS). 2010. California Geography, Geology, Hazards, and Natural History Information. http://education.usgs.gov/california/resources.html

USGS. 2009. Groundwater Availability of the Central Valley Aquifer, California, Professional Paper 1766.

U.S. Global Change Research Program (USGRP), National Assessment Synthesis Team. 2001. Climate Change Impacts on the United States, Potential Consequences of Climate Variability and Change.

Water Replenishment District (WRD). 2010. Agenda Package for the Special Meeting of the Board of Directors of the Water Replenishment District of Southern California on November 19, 2010.

Western Regional Climate Center. 2009. http://www.wrcc.dri.edu/ Website accessed August 14, 2009.

Appendix A
California Water Chronology

1769 First permanent Spanish settlements; water rights established.

1848 Gold discovered on the American River.

Treaty of Guadalupe signed, California ceded from Mexico, California republic established.

1849 First major levee constructed in Delta on Grand Island.

1850 California granted statehood.

Congress adopts Arkansas Swamp Act to sell floodplain land to developers who would construct levees and drainage systems.

1852 Wheaton Mining Dam constructed at La Grange on the Tuolumne River.

1852 Hydraulic mining activities begin.

1854 Large irrigation facilities constructed to divert Merced River water.

1859-1865 Large irrigation facilities constructed to divert Tule River water.

1868 California Legislature adopts Green Act, allowing formation of reclamation districts with taxing authority.

1870s-1880s Diversions and canals constructed to convey water from Kings, San Joaquin, Kern, and Merced rivers.

1870 State Fish Commission created to enforce catch restrictions and require fish ladders for all physical obstructions.

1871 Mendota Dam (Weir) constructed.

1880s Tulare Lake water quality extremely poor due to return flows and unsuitable for irrigation or potable water supplies.

Large salmon canneries in operation on Sacramento River.

1880 First flood control plan for the Sacramento Valley developed by State Engineer William Hammond Hall.

	California Legislature approves Drainage Act to provide flood control in Central Valley.
1884	Federal circuit court decision in *Woodruff v. North Bloomfield* requires termination of hydraulic mining debris discharges into California rivers.
1886	California Supreme Court decision in *Lux v. Haggin* reaffirms legal preeminence of riparian rights, upheld again 40 years later.
1892	Conservationist John Muir founds Sierra Club.
	Congress establishes California Debris Commission to remove mining debris from rivers and navigable waters.
1893	Modesto Irrigation District and Turlock Irrigation District constructed La Grange Dam on Tuolumne River.
1895	Debris dams constructed along Sacramento River tributaries, including the American and Yuba rivers.
1900	Bear River Dam completed.
1901	First California deliveries from the Colorado River made to farmland in the Imperial Valley.
1902	US Bureau of Reclamation established by the Reclamation Act of 1902.
	Union Dam completed on North Fork Stanislaus River.
1905	First bond issue for the city of Los Angeles' Owens Valley project; second bond issue in 1907 approved for actual construction.
	Colorado River flooding diverts the river into Imperial Valley, forming the Salton Sea.
1908	City of San Francisco's filings for Hetch Hetchy project approved.
1912	Goodwin Dam completed on Stanislaus River.
1913	Los Angeles Aqueduct begins service.
	California Legislature passes Raker Act, allowing San Francisco to divert water from Tuolumne River.
	Almanor Dam completed on North Fork Feather River.
1914	Sacramento River Flood Control Project levees constructed to minimize flooding due to increased elevation of riverbed caused by mining debris.
1915	Oakdale Irrigation District and South San Joaquin Irrigation District begin diversions from Stanislaus River.
1916	Main Strawberry Dam completed on South Fork Stanislaus River.
1919	Merced Irrigation District constructs Exchequer Dam and Power Plant on Merced River.
1920	Col. Robert B. Marshall of the US Geological Survey proposes statewide plan for water conveyance and storage.
1922	Colorado River Compact appropriates 7.5 million acre-feet per year to each of the river's two basins.

1923 Hetch Hetchy Valley flooded to produce water supply for San Francisco despite years of protest by John Muir and other conservationists.

Modesto Irrigation District and Turlock Irrigation District construct Don Pedro Reservoir on Tuolumne River.

East Bay Municipal Utility District formed.

1924 Melones Dam constructed on Stanislaus River.

(Old) Bullards Bar Dam completed on Yuba River.

1925 Calaveras Dam completed on Calaveras River.

1927 Lake Briton Dam and Pit River No. 3 and No. 4 dams completed on Pit River.

1928 Congress passes Boulder Canyon Act, authorizing construction of Boulder (Hoover) Dam and other Colorado River facilities.

Federal government assumes most costs of the Sacramento Valley Flood Control System with passage of the Rivers and Harbors Act.

California Constitution amended to require that all water use be “reasonable and beneficial.”

St. Francis Dam collapses, flooding the Santa Clarita Valley, killing more than 450 people.

Worst drought of the 20th century begins; ends in 1934, establishing benchmark for water project storage and transfer capacity of all major water projects.

1929 Pardee Dam and Mokelumne Aqueduct completed on Mokelumne River.

1930 Lyons Dam completed on South Fork Stanislaus River.

1930s Fertilizers and vector poisons introduced on farmlands.

1931 State Water Plan published, outlining utilization of water resources on a statewide basis.

The federal government and California State Water Resources Commission (Hoover-Young Commission) recommend that the federal government construct the Central Valley Project and that the state operate the facilities.

County of Origin Law passed, guaranteeing counties the right to reclaim water from an exporter if it is needed in the area of origin.

Salt Springs Dam completed on North Fork Mokelumne River.

1933 Central Valley Project Act passed.

State of California authorizes bonds for $170 million for the Central Valley Project (Shasta Dam and Power Plant, Friant Dam and Power Plant, Contra Costa Canal, Madera Canal, Friant Kern Canal, other dams and pumps on the San Joaquin River, transmission lines from Shasta to Antioch, and a pump between the Sacramento and San Joaquin rivers.

1934 Construction starts on All-American Canal in the Imperial Valley (first deliveries in 1941) and on Parker Dam on the Colorado River.

San Francisco constructs Hetch Hetchy Aqueduct from Tuolumne River.

1937	Rivers and Harbors Act authorizes construction of initial Central Valley Project features by US Army Corps of Engineers.
1940	Metropolitan Water District of Southern California’s Colorado River Aqueduct completed; first deliveries in 1941.
	Congress reauthorizes the Central Valley Project, restates the purposes of the project, and allows for construction of local distribution systems as part of Central Valley Project construction projects.
	Water diversions begin at Contra Costa Canal from the Delta (first CVP diversion).
1944	Mexican-US Treaty guarantees Mexico 1.5 million acre-feet per year from Colorado River.
	Shasta Dam completed and water diversions begin on Sacramento River.
1945	State Water Resources Control Board created.
1947	Friant Dam completed on San Joaquin River.
1949	Friant Kern Canal completed.
1950	Keswick Dam completed on Sacramento River.
	Anderson-Cottonwood diversions begin.
1951	State authorizes the Feather River Project Act (later to become the State Water Project).
	Delta Cross Channel, Delta-Mendota Canal, and Tracy Pumping Plant completed.
	First deliveries from Shasta Dam to the San Joaquin Valley.
1954	Pine Flat Dam completed on Kings River.
	Isabella Dam completed on Kern River.
1955	Flood in the Sacramento Valley kills 38 people.
	Nimbus Dam and Power Plant completed on American River.
1956	Folsom Dam completed on American River.
1957	California Water Plan (Bulletin 3) published.
	Beardsley and Donnell dams completed on Middle Fork Stanislaus River.
	Tulloch Dam completed on Stanislaus River.
	Tracy fish collection facility completed.
1959	Delta Protection Act resolves some issues of legal boundaries, salinity control and water export.
	Putah South Canal diversions begin.
1960	Burns-Porter Act ratified by voters; $1.75 million bond issue to assist statewide water development.
1961	California Department of Water Resources establishes Interagency Delta Committee to evaluate solutions to Delta problems.
	Success Dam completed on Tule River.

1962	Terminus Dam completed on Kaweah River.
	South Bay Aqueduct completed.
1963	*Arizona v. California* lawsuit decided by US Supreme Court, allocating 2.8 million acre-feet of Colorado River water per year to Arizona.
	Whiskeytown Dam completed.
	New Hogan Dam completed on Calaveras River.
	Camanche Dam completed on Mokelumne River.
	Lewiston Dam, Carr Power Plant, and Clear Creek Tunnel completed.
1964	Partially completed Oroville Dam helps save Sacramento Valley from flooding.
	Trinity Dam completed on Trinity River.
	Red Bluff Diversion Dam completed on Sacramento River.
1966	Construction begins on New Melones Dam on the Stanislaus River after 20 years of controversy over the reservoir’s size and environmental impacts; completed in 1978.
1967	State Water Project Delta Pumps and California Aqueduct completed.
	Oroville Dam completed on Feather River.
	San Luis Canal and Dam completed.
	New Exchequer Dam completed on Merced River.
	California State Water Resources Control Board adopts Water Quality Control Plan for Sacramento-San Joaquin Delta pursuant to Federal Water Pollution Control Act of 1965.
1968	Congress authorizes Central Arizona Project to deliver 1.5 million acre-feet of Colorado River water a year to Arizona.
	Congress passes Wild and Scenic Rivers Act.
1969	New Bullards Bar Dam completed on Yuba River.
1970	Passage of the National Environmental Quality Act, California Environmental Quality Act and California Endangered Species Act.
	New Don Pedro Dam completed on Tuolumne River.
1971	California State Water Resources Control Board adopts Water Rights Decision 1379 establishing Delta water quality standards.
	Tehama-Colusa Canal and Pumping Plant completed.
	Tehama-Colusa Canal Fish Facility completed.
1972	California Legislature passes Wild and Scenic Rivers Act preserving the North Coast’s remaining free-flowing rivers from development.
	Federal Clean Water Act (CWA) passed.
1973	First State Water Project deliveries to Southern California.

1974 Congress passes Safe Drinking Water Act.

1976-1977 Drought

1978 State Water Board issues Water Rights Decision 1485 setting Delta water quality standards.

New Melones Dam completed on Stanislaus River.

1980 State-designated wild and scenic rivers placed under federal Act's protection.

1982 Proposition 9, the Peripheral Canal package, overwhelmingly defeated in statewide vote.

Reclamation Reform Act raises from 160 acres to 960 acres the amount of land a farmer can own and still receive low-cost federal water.

1983 California Supreme Court in *National Audubon Society v. Superior Court* rules that the public trust doctrine applies to Los Angeles' diversion from tributary streams of Mono Lake.

Dead and deformed waterfowl discovered at Kesterson Reservoir, pointing to problems of selenium-tainted agricultural drainage water.

1986 Ruling by State Court of Appeals (*Racanelli* Decision) directs the State Water Board to consider all beneficial uses, including instream needs, of Delta water when setting water quality standards.

Passage of Safe Drinking Water and Toxic Enforcement Act (Proposition 65) prohibiting discharge of toxic chemicals into state waters.

Coordinated Operation Agreement for Central Valley Project and State Water Project operations in the Delta signed.

1987 State Water Board's Bay-Delta Proceedings begin to revise D-1485 water quality standards.

State Water Project's North Bay Aqueduct completed.

1989 In a separate challenge to Los Angeles' Mono Basin water rights, an appellate court holds that fish are a public trust resource in *California Trout v. State Water Resources Control Board*.

Metropolitan Water District and Imperial Irrigation District agree that Metropolitan Water District will pay for agricultural water conservation projects and receive the water conserved.

1991 MOU signed to implement urban water conservation programs.

Inyo County and Los Angeles agree to jointly manage Owens Valley water, ending 19 years of litigation.

West Coast's first municipal sea water desalination plant opens on Catalina Island.

1992 Congress approves landmark Central Valley Project Improvement Act.

1993 Federal court rules in *Natural Resource Defense Council v. Patterson* that the Central Valley Project must conform with State law requiring release of flows for fishery preservation below dams.

Central Arizona Project declared complete by the federal government.

1994 State Water Board amends Los Angeles' water rights licenses to Mono Lake.

Bay-Delta Accord sets interim Delta water quality.

CALFED Bay-Delta Program planning initiated.

1995 State Water Board adopts new water quality plan for the Delta and begins hearings on water rights.

1997 New Year's storms cause state's second most devastating flood of the century.

State Water Project's Santa Barbara Aqueduct completed.

1999 Sacramento splittail minnow and spring-run Chinook salmon added to federal endangered species list.

Diamond Valley Reservoir completed.

2000 CALFED Record of Decision signed by state and federal agencies.

2002 Voters approve Proposition 50, a $3.44 billion bond issue to fund improvements in water quality and reliability.

2003 Interior Secretary orders California's Colorado River allocation limited to 4.4 million acre-feet; water users sign Quantification Settlement Agreement.

State Water Project contractors, DWR and environmental groups settle lawsuit over the Monterey Amendment. State Water Project, Central Valley Project and respective contractors reach tentative agreement on "Napa Proposal" water-sharing plan.

DWR issues draft EIR on increasing pumping level out of Delta to 8,500 cubic feet per second.

US Fish and Wildlife Service removes Sacramento splittail from federal Endangered Species Act list of threatened species.

2004 State Water Board initiates review of 1995 Water Quality Control Plan.

Congress approves long-awaited legislation to re-authorize CALFED.

2005 Scientific surveys of the Sacramento-San Joaquin River Delta and Suisun Marsh reveal ongoing, sweeping population crash of native pelagic fish.

Legislation directs DWR to evaluate the future of the Delta.

2006 Coalition of fishing groups sues DWR, alleging the agency never obtained proper legal authority to take endangered fish while exporting water.

2007 State Water Project pumping operations shut down to protect endangered delta smelt (Wanger Decision).

DWR estimates that Delta levees are vulnerable to massive failure if major earthquake occurs.

Seven Colorado River states agree to new drought rules and shortage criteria.

Governor Schwarzenegger appoints independent Delta Vision "Blue Ribbon" Task Force.

Delta Vision Task Force releases final report.

Other Delta planning processes continue.

2008 DWR initiates Bay-Delta Conservation Plan EIS/EIR.

Governor Schwarzenegger declares statewide drought after second dry/critical year.

Delta Vision Blue Ribbon Task Force releases strategic plan.

2009 Legislature passes the Sacramento – San Joaquin Delta Reform Act, creating the Delta Stewardship Council as an independent state agency and directing the Delta Stewardship Council to adopt a comprehensive management plan for the Delta no later than January 1, 2012.

(Chronology adapted from the California Water Plan [DWR, 2009] and the Water Education Foundation Layperson's Guides.)

Appendix B
Major Dams

Table B-1
Dams in Watersheds Tributary to the Delta or that Provide Water Supplies to Users of Water from Watersheds Tributary to the Delta with Storage Capacity Greater than 10,000 acre-feet

Stream	Dam Name	Owner	County	Year	Capacity (acre-feet)
Dams in Watersheds Tributary to the Delta					
American River	Folsom	Reclamation	Sacramento	1956	975,000
Arroyo Valle	Del Valle	DWR	Alameda	1968	77,100
Bear River	Rollins	Nevada Irrigation District	Nevada	1965	66,000
Bear River	Lower Bear River	Pacific Gas & Electric Company	Amador	1952	48,750
Bear River	Camp Far West	South Sutter Water District	Yuba	1963	104,500
Big Creek	Huntington Lake 1	Southern California Edison Company	Fresno	1917	88,834
Big Dry Creek & Dog Creek	Big Dry Creek	Fresno Metropolitan Flood Control District	Fresno	1948	30,200
Big Grizzly Creek	Grizzly Valley (Lake Davis)	DWR	Plumas	1966	83,000
Bucks Creek	Bucks Storage	Pacific Gas & Electric Company	Plumas	1928	103,000
Butt Creek	Butt Valley	Pacific Gas & Electric Company	Plumas	1924	49,800
Cache Creek	Cache Creek	Yolo County Flood Control and Water Conservation District	Lake	1914	315,000
Calaveras River	New Hogan	USACE	Calaveras	1963	317,000
Canyon Creek	French Lake	Nevada Irrigation District	Nevada	1859	12,500
Canyon Creek	Bowman	Nevada Irrigation District	Nevada	1927	64,000
Cedar Creek	Tule Lake	John Hancock Mutual Ins Co	Lassen	1904	39,500
Cherry Creek	Cherry Valley	San Francisco Public Utilities Commission	Tuolumne	1956	273,500
Chowchilla River	Buchanan	USACE	Madera	1975	150,000
Clear Creek	Whiskeytown	Reclamation	Shasta	1963	241,100
Cottonwood Creek	Thermalito Forebay	DWR	Butte	1967	11,768

Table B-1
Dams in Watersheds Tributary to the Delta or that Provide Water Supplies to Users of Water from Watersheds Tributary to the Delta with Storage Capacity Greater than 10,000 acre-feet

Stream	Dam Name	Owner	County	Year	Capacity (acre-feet)
Deer Creek	Scotts Flat	Nevada Irrigation District	Nevada	1948	49,000
Dry Creek	Virginia Ranch	Browns Valley Irrigation District	Yuba	1963	57,000
Eleanor Creek	Lake Eleanor	San Francisco Public Utilities Commission	Tuolumne	1918	28,600
Feather River	Thermalito Diversion	DWR	Butte	1967	13,328
Feather River	Oroville	DWR	Butte	1968	3,537,577
Feather River	Thermalito Afterbay	DWR	Butte	1967	57,041
Fordyce Creek	Lake Fordyce	Pacific Gas & Electric Company	Nevada	1873	48,900
Fresno River	Hidden	USACE	Madera	1975	90,000
Gerle Creek	Loon Lake	Sacramento Municipal Utility District	El Dorado	1963	76,500
Hamilton Creek	Indian Ole	Pacific Gas & Electric Company	Lassen	1924	24,800
Helms Creek	Courtright	Pacific Gas & Electric Company	Fresno	1958	123,300
Highland Creek	New Spicer Meadow	Calaveras County Water District	Tuolumne	1989	189,000
Indian Creek	Antelope	DWR	Plumas	1964	22,566
Iron Canyon Creek	Iron Canyon	Pacific Gas & Electric Company	Shasta	1965	24,300
Jackson Creek	Jackson Creek	Jackson Valley Irrigation Dist	Amador	1965	22,000
Little Butte Creek	Paradise	Paradise Irrigation Dist	Butte	1957	11,500
Little Last Chance Creek	Frenchman	DWR	Plumas	1961	55,477
Little Stony Creek	East Park	Reclamation	Colusa	1910	51,000
Los Banos Creek	Los Banos Detention	Reclamation	Merced	1965	34,600
Lost Creek	Sly Creek	South Feather Water And Power Agency	Butte	1961	65,050
Mariposa Creek	Mariposa	USACE	Mariposa	1948	15,000
Martis Creek	Martis Creek	USACE	Nevada	1972	20,400
McCloud River	McCloud	Pacific Gas & Electric Company	Shasta	1965	35,300
Merced River	New Exchequer	Merced Irrigation Dist	Mariposa	1967	1,032,000
Middle Fork American River	L. L. Anderson	Placer County Water Agency	Placer	1965	155,500
Middle Fork Stanislaus River	Beardsley	Tri-Dam Project	Tuolumne	1957	77,600
Middle Fork Stanislaus River	Donnells	Tri-Dam Project	Tuolumne	1958	56,893
Middle Fork Yuba River	Jackson Meadows	Nevada Irrigation District	Nevada	1965	52,500
Mokelumne River	Camanche	East Bay Municipal Utilities District	San Joaquin	1963	417,120
Mokelumne River	Pardee	East Bay Municipal Utilities District	Amador	1929	197,950

Table B-1
Dams in Watersheds Tributary to the Delta or that Provide Water Supplies to Users of Water from Watersheds Tributary to the Delta with Storage Capacity Greater than 10,000 acre-feet

Stream	Dam Name	Owner	County	Year	Capacity (acre-feet)
Mono Creek	Vermilion Valley	Southern California Edison Company	Fresno	1954	125,000
North Fork American River	North Fork	USACE	Placer	1939	14,700
North Fork Cache Creek	Indian Valley	Yolo County Flood Control and Water Conservation District	Lake	1976	300,000
North Fork Feather River	Lake Almanor	Pacific Gas & Electric Company	Plumas	1927	1,308,000
North Fork Kings River	Wishon	Pacific Gas & Electric Company	Fresno	1958	118,000
North Fork Mokelumne River	Salt Springs	Pacific Gas & Electric Company	Amador	1931	141,900
North Fork Willow Creek	Crane Valley Storage	Pacific Gas & Electric Company	Madera	1910	45,410
North Yuba River	New Bullards Bar	Yuba County Water Agency	Yuba	1970	969,600
Old River	Clifton Court Forebay	DWR	Contra Costa	1970	29,000
Pilot Creek	Mark Edson	Georgetown Divide Public Utilities District	El Dorado	1962	20,000
Pit River	Pit No.6	Pacific Gas & Electric Company	Shasta	1965	15,700
Pit River	Pit No.3	Pacific Gas & Electric Company	Shasta	1925	34,600
Pit River	Pit No. 7	Pacific Gas & Electric Company	Shasta	1965	34,000
Red Rock Creek	Red Rock No 1	Edgar S. (Red) Roberts	Lassen	1893	10,000
Rock & Little John Creeks	Farmington	USACE	San Joaquin	1951	52,000
Rock Creek	Salt Springs Valley	Rock Creek Water District	Calaveras	1882	10,900
Rubicon River	Lower Hell Hole	Placer County Water Agency	Placer	1966	208,400
Sacramento River	Box Canyon	Siskiyou County Flood Control and Water Conservation District	Siskiyou	1969	26,000
Sacramento River	Keswick	Reclamation	Shasta	1950	23,772
Sacramento River	Shasta	Reclamation	Shasta	1945	4,552,000
San Joaquin River	Big Creek No. 7	Southern California Edison Company	Fresno	1951	35,000
San Joaquin River	Mammoth Pool	Southern California Edison Company	Fresno	1960	123,000
San Joaquin River	Friant	Reclamation	Fresno	1942	520,500
San Luis Creek	O'Neill	Reclamation	Merced	1967	56,400
San Luis Creek	B.F. Sisk	Reclamation	Merced	1967	2,041,000
Silver Creek	Union Valley	Sacramento Municipal Utility District	El Dorado	1963	230,000
Silver Fork	Caples Lake	El Dorado Irrigation District	Alpine	1922	21,580
Simmons Creek	Woodward	South San Joaquin Irrigation District	Stanislaus	1918	35,000

Table B-1
Dams in Watersheds Tributary to the Delta or that Provide Water Supplies to Users of Water from Watersheds Tributary to the Delta with Storage Capacity Greater than 10,000 acre-feet

Stream	Dam Name	Owner	County	Year	Capacity (acre-feet)
Sly Park Creek	Sly Park	El Dorado Irrigation District	El Dorado	1955	41,000
South Fork American River	Slab Creek	Sacramento Municipal Utility District	El Dorado	1967	16,600
South Fork Feather River	Little Grass Valley	South Feather Water And Power Agency	Plumas	1961	93,010
South Fork San Joaquin River	Florence Lake	Southern California Edison Company	Fresno	1926	64,406
South Fork Silver Creek	Ice House	Sacramento Municipal Utility District	El Dorado	1959	37,120
South Fork Stanislaus River	Main Strawberry	Pacific Gas & Electric Company	Tuolumne	1916	18,312
South Fork Yuba River	Lake Spaulding	Pacific Gas & Electric Company	Nevada	1913	74,773
Stanislaus River	New Melones	Reclamation	Calaveras	1979	2,400,000
Stanislaus River	Tulloch	Tri-Dam Project	Calaveras	1958	68,400
Stevenson Creek	Shaver Lake	Southern California Edison Company	Fresno	1927	135,283
Stockdill Slough	Dorris	USFWS	Modoc	1930	11,100
Stony Creek	Black Butte	USACE	Tehama	1963	143,700
Stony Creek	Stony Gorge	Reclamation	Glenn	1928	50,350
Summit Creek	Relief	Pacific Gas & Electric Company	Tuolumne	1910	15,122
Susan River	McCoy Flat	Lassen Irrigation Company	Lassen	1891	17,290
Trinity River	Lewiston	Reclamation	Trinity	1963	14,660
Trinity River	Trinity	Reclamation	Trinity	1962	2,447,650
Tule River	Success	USACE	Tulare	1961	82,300
Tuolumne River	O' Shaughnessy	San Francisco Public Utilities Commission	Tuolumne	1923	360,000
Tuolumne River	Don Pedro	Turlock Irrigation District	Tuolumne	1971	2,030,000
Tuolumne River	Modesto Reservoir	Modesto Irrigation District	Stanislaus	1911	29,000
Tuolumne River	Turlock Lake	Turlock Irrigation District	Stanislaus	1915	45,600
Yuba River	Englebright	USACE	Yuba	1941	70,000
Dams in Tulare Lake Region that Serve Users of Water from Watersheds Tributary to the Delta					
Kaweah River	Terminus	USACE	Tulare	1962	143,000
Kern River	Isabella	USACE	Kern	1953	568,000
Kings River	Pine Flat	USACE	Fresno	1954	1,000,000
Offstream Storage	Buena Vista	J G Boswell & Co	Kern	1890	205,000
Dams in San Francisco Bay Area that Serve Users of Water from Watersheds Tributary to the Delta					
Bear Creek	Briones	East Bay Municipal Utilities District	Contra Costa	1964	67,520
Calaveras Creek	Calaveras	City & County of San Francisco	Alameda	1925	100,000
Conn Creek	Conn Creek	City of Napa	Napa	1946	31,000

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Dams in Watersheds Tributary to the Delta or that Provide Water Supplies to Users of Water from Watersheds Tributary to the Delta with Storage Capacity Greater than 10,000 acre-feet

Stream	Dam Name	Owner	County	Year	Capacity (acre-feet)
Coyote Creek	Coyote	Santa Clara Valley Water District	Santa Clara	1936	23,666
Coyote River	Leroy Anderson	Santa Clara Valley Water District	Santa Clara	1950	91,280
Gordon Valley Creek	Lake Curry	City of Vallejo	Napa	1926	10,700
Kellogg Creek	Los Vaqueros	Contra Costa Water District	Contra Costa	1997	100,000
Los Gatos Creek	James J. Lenihan	Santa Clara Valley Water District	Santa Clara	1953	21,430
Offstream Storage	San Justo	Reclamation	San Benito	1958	10,300
Putah Creek	Monticello	Reclamation	Napa	1957	1,602,000
San Antonio Creek	James H Turner	City & County of San Francisco	Alameda	1964	50,500
San Benito River	Hernandez	San Benito County Water District	San Benito	1962	18,000
San Leandro Creek	Chabot	East Bay Municipal Utilities District	Alameda	1892	10,281
San Leandro Creek	New U San Leandro	East Bay Municipal Utilities District	Alameda	1977	42,000
San Mateo Creek	Lower Crystal Springs	City & County of San Francisco	San Mateo	1888	57,910
San Pablo Creek	San Pablo	East Bay Municipal Utilities District	Contra Costa	1920	43,193
San Mateo Creek	San Andreas	City & County of San Francisco	San Mateo	1870	19,027
Uvas Creek	Uvas	Santa Clara Valley Water District	Santa Clara	1957	10,000
Dams in Southern California that Serve Users of Water from Watersheds Tributary to the Delta					
Bear Creek	Bear Valley	Big Bear Municipal Water District	San Bernardino	1911	74,000
Bernasconi Pass	Perris	DWR	Riverside	1973	131,452
Boulder Creek	Cuyamaca	Helix Water District	San Diego	1887	11,740
Bouquet Creek	Bouquet Canyon	City of Los Angeles	Los Angeles	1934	36,505
Castaic Creek	Castaic	DWR	Los Angeles	1973	323,700
Castaic Creek	Elderberry Forebay	City of Los Angeles	Los Angeles	1974	28,400
Colorado River	Parker	Reclamation	San Bernardino	1938	648,000
Copper Basin	Copper Basin	Metropolitan Water District of Southern California	San Bernardino	1938	22,000
Cottonwood Creek	Barrett	City of San Diego	San Diego	1922	44,755
Cottonwood Creek	Morena	City of San Diego	San Diego	1912	50,206
Domenigoni Valley Creek	Diamond Valley Lake	Metropolitan Water District of Southern California	Riverside	2000	800,000
Green Val Road Creek	Ramona	Ramona Municipal Water District	San Diego	1988	12,200
Little Bear Creek	Lake Arrowhead	Arrowhead Lake Association	San Bernardino	1922	48,000

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Stream	Dam Name	Owner	County	Year	Capacity (acre-feet)
Los Angeles River	Sepulveda	USACE	Los Angeles	1941	17,425
Otay River	Savage	City of San Diego	San Diego	1919	49,510
Owens River	Tinemaha	City of Los Angeles	Inyo	1928	16,405
Owens River	Long Valley	City of Los Angeles	Mono	1941	183,465
Piru Creek	Pyramid	DWR	Los Angeles	1973	180,000
Rose Valley	Haiwee	City of Los Angeles	Inyo	1913	46,600
Rush Creek	Grant Lake	City of Los Angeles	Mono	1940	47,525
San Diego River	El Capitan	City of San Diego	San Diego	1934	112,800
San Dieguito River	Hodges, Lake	City of San Diego	San Diego	1918	37,700
San Fernando Creek	Lower San Fernando	City of Los Angeles	Los Angeles	1918	10,000
San Fernando Creek	Los Angeles Reservoir	City of Los Angeles	Los Angeles	1977	10,000
San Gabriel River	Santa Fe	USACE	Los Angeles	1949	32,109
San Gabriel River	Whittier Narrows	USACE	Los Angeles	1957	67,060
San Gabriel River	San Gabriel No 1	Los Angeles County Department of Public Works	Los Angeles	1938	44,183
San Gabriel River	Morris	Los Angeles County Department of Public Works	Los Angeles	1935	27,500
San Jacinto River	Railroad Canyon	Elsinore Valley Municipal Water District	Riverside	1928	11,586
San Luis Rey River	Henshaw	Vista Irrigation District	San Diego	1923	50,000
San Vicente Creek	San Vicente	City of San Diego	San Diego	1943	250,000
Santa Ana River	Prado	USACE	Riverside	1941	314,400
Santa Ana River	Seven Oaks	San Bernardino County Department of Transportation And Flood Control District	San Bernardino	1999	145,600
Santa Ysabel Creek	Sutherland	City of San Diego	San Diego	1954	29,000
Santiago Creek	Villa Park	County of Orange	Orange	1963	15,600
Santiago Creek	Santiago Creek	Serrano Water District & Irvine Ranch Water District	Orange	1933	25,000
Stone Canyon Creek	Stone Canyon	City of Los Angeles	Los Angeles	1924	10,372
Sweetwater River	Sweetwater Main	Sweetwater Authority	San Diego	1888	27,700
Sweetwater River	Lake Loveland	Sweetwater Authority	San Diego	1945	25,400
Temecula Creek	Vail	Rancho California Water District	Riverside	1949	51,000
Cajalco Creek	Mathews	Metropolitan Water District of Southern California	Riverside	1938	182,000
Escondido Creek	Olivenhain	San Diego County Water Authority	San Diego	2003	24,900

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Stream	Dam Name	Owner	County	Year	Capacity (acre-feet)
San Jacinto River	Lake Hemet	Lake Hemet Municipal Water District	Riverside	1895	14,000
Tucalota Creek	Robert A Skinner	Metropolitan Water District of Southern California	Riverside	1973	43,800
Tujunga Wash	Hansen	USACE	Los Angeles	1940	25,446
Walnut Creek	Puddingstone	Los Angeles County Department of Public Works	Los Angeles	1928	16,342
West Fork Mojave River	Mojave	USACE	San Bernardino	1971	89,700
West Fork Mojave River	Cedar Springs	DWR	San Bernardino	1971	78,000
Dams in Central Coast Region of California that Serve Users of Water from Watersheds Tributary to the Delta					
Nacimiento Rv	Nacimiento	Monterey Co Water Res Agency	San Luis Obispo	1957	350,000
Cuyama River	Twitchell	US Bureau of Reclamation	San Luis Obispo	1958	240,000
Santa Ynez River	Bradbury	US Bureau of Reclamation	Santa Barbara	1953	205,000
Arroyo Grande Cr	Lopez	San Luis Obispo Co Fcwcd	San Luis Obispo	1969	52,500
Old Creek	Whale Rock	Whale Rock Commission	San Luis Obispo	1960	40,662
Salinas River	Salinas	Corps of Engineers	San Luis Obispo	1942	26,000
San Benito River	Hernandez	San Benito Co Water Dist	San Benito	1962	18,000
Offstream	San Justo	US Bureau of Reclamation	San Benito	1958	10,300
Nacimiento Rv	Nacimiento	Monterey Co Water Res Agency	San Luis Obispo	1957	350,000

Source: DWR Division of Safety of Dams, 2010

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